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1 October 1988 to
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AFAL Technical Objective Document FY 90

August 1988

Approved for Public Release

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Astronautics
Laboratory

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This document has been reviewed and is approved.

James R. Nunn

JAMES R. NUNN, Colonel, USAF
Commander, Air Force Astronautics Laboratory

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[illegible] report is a summary of technical objectives and approaches for research, [illegible] development, and advanced development efforts being pursued, and to be [illegible] the Air Force Astronautics Laboratory between FY 89-93.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The Air Force Technical Objective Document (TOD) program is an integral part of the process by which the Air Force plans and formulates a detailed technology program to support the development and acquisition of Air Force weapons systems.

Each Air Force laboratory annually formulates its Science and Technology (S&T) program in response to available guidance based on USAF requirements, the identification of scientific and technological opportunities, and the needs of present and projected systems. These plans include proposed efforts to achieve desired capabilities, to resolve known technical problems, and to capitalize on new technical opportunities. The proposed efforts undergo a lengthy program formulation and review process. Generally, the criteria applied during the formulation and review are responsive to stated objectives and known requirements, scientific content and merit, program balance, developmental and life cycle costs, and consideration of payoff versus risk.

It is fully recognized that the development and accomplishment of the Air Force technical program are products of the teamwork on the part of the Air Force laboratories and the industrial and academic research and development community. The TOD program is designed to provide to industry and the academic community, necessary information on the Air Force laboratories' planned technology programs. Each laboratory's TOD is extracted from its S&T planning activity.

Specific objectives are:

a. To provide planning information for independent research and development programs.

b. To improve the quality of the unsolicited proposals and R&D procurements.

c. To encourage face-to-face discussions between non-Government scientists and engineers and their Air Force counterparts.

One or more TODs have been prepared by each Air Force laboratory that has responsibility for a portion of the Air Force S&T programs. Classified and limited distribution TODs are available from the Defense Technical Information Center (DTIC) and unclassified/unlimited TODs are available from the National Technical Information Service (NTIS).

The AFAL TOD contains a general overview of the Laboratory and its planned program. The appendix contains a program listing of our FY-89 and 90 expected new competitive contracted programs. These program listings are extracts from preliminary internal planning documents and should be viewed in that light. It is also important to remember that at the time this program list was prepared, it was a "snapshot-in-time" and is subject to change.

HOW TO USE THIS DOCUMENT

Unsolicited proposals to conduct programs leading to the attainment of any of the objectives presented in this document may be submitted directly to an Air Force laboratory. However, before submitting a formal proposal, we encourage you to discuss your approach with the laboratory point of contact. After your discussion or correspondence with laboratory personnel, you will be better prepared to write your proposal.

As stated in the "AFSC Guide for Unsolicited Proposals," elaborate brochures or presentations are definitely not desired (copies of this informative guide on unsolicited proposals are available from the Air Force Systems Command/DAPE, Andrews Air Force Base, Washington, DC 20334-5000). The "ABCs" of successful proposals are accuracy, brevity, and clarity. It is extremely important that your letter be prepared to encourage its reading, to facilitate its understanding, and to impart an appreciation of the ideas you desire to convey. Specifically, your letter should include the following:

1. Name and address of your organization.

2. Type of organization (profit, non-profit).

3. Concise title and abstract of the proposed research and the statement indicating that the submission is an unsolicited proposal.

4. An outline and discussion of the purpose of the research, the method of attack upon the problem, and the nature of the expected results.

5. Name and research experience of the principal investigator.

6. A suggestion as to the proposed starting and completion dates.

7. An outline of the proposed budget, including information on equipment, facility, and personnel requirements.

8. Names of any other Federal agencies receiving the proposal (this is extremely important).

9. Brief description of your facilities, particularly those which would be used in your proposed research effort.

10. Brief outline of your previous work and experience in the field.

11. If available, you should include a description brochure and a financial statement.

As you read through the pages that follow, you may see a field of endeavor where your organization can contribute to the achievement of a specific technical goal. If such is the case, you are invited to discuss the objective further with the scientist or engineer identified with that objective. Further, you may have completely new ideas not considered in this document which, if brought to the attention of the proper organization,

can make a significant contribution to our military technology. We will always maintain an open mind in evaluating any new concepts which, when successfully pursued, would improve our future operational capability.

On behalf of the United States Air Force, you are invited to study the objectives listed in this document and to discuss them with the responsible Air Force personnel. Your ideas and proposals, whether in response to the TODs or not, are most welcome.

The Air Force Astronautics Laboratory's technology program is organized into applications oriented major thrusts; one for each of the three major rocket propulsion applications areas, i.e., space systems, ballistic missiles, and air-launched missiles. Two other major thrusts make up the remainder of the Laboratory's program; one for fundamental technologies which is (or will be) applied to several application areas, and one for, generally, non-propulsive space technologies which can best be described as Space Vehicle Technology. The points of contact, should you desire additional information, are:

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Ballistic Missile Propulsion Technology Air-Launched Missile Propulsion Technology	Mr Luciano Sedillo AFAL/XRX Autovon 525-5341 Commercial (805) 275-5341
Fundamental Technologies	Mr Wayne Roe AFAL/XRX Autovon 525-5206 Commercial (805) 275-5206
Strategic Defense Initiative Technology	Col Thomas W. Redmond AFAL/CR Autovon 525-5324 Commercial (805) 275-5324

LABORATORY MISSION

The Air Force Astronautics Laboratory (AFAL) is the principal AFSC organization charged with planning and executing USAF research, exploratory and advanced development programs for interdisciplinary space technology and rocket propulsion. Space technology includes spacecraft technology, launch vehicle technology, launch and in-space operations, and logistics technology. Rocket propulsion includes propellants, combustion, plume phenomenology, rocket propulsion materials and structures, solid propellant, rocket motors, liquid propellant rocket feed systems and engines, electric propulsion, hazard phenomena and assessment, and rocket test techniques and instrumentation. There are two parts to the AFAL mission - first to develop new technology for the Air Force missiles and space systems of the future; and second to provide technical support to other organizations within the Air Force, particularly the Systems Program Offices (SPOs) that produce the end items. This mission is graphically depicted in Figure 1.

The technology advancement programs cover the complete spectrum of detailed basic research (6.1), exploratory development (6.2) and advanced development (6.3). The Laboratory is responsible for maintaining a superior technical base in all types of rocket propulsion and interdisciplinary space-related disciplines which will provide options for the development of future high performance Air Force systems and to prevent technological surprise. The technical management assistance includes engineering and scientific consultation, technical direction of programs, managing contractual efforts and executing in-house analytical and experimental programs.

INVESTMENT STRATEGY

The Laboratory strives to have a balanced investment strategy that takes into account (1) Air Force needs as stated by the system users, (2) Air Force mission capability deficiencies as identified in documents such as the Air Force Space Plan, Military Space Systems Technology Plan (MSSTP), and the Logistics Long Range Planning Guide, (3) AFSC Forecast II, and (4) basic technological advances, otherwise known as "Technology Push." We use an in-house management council, made up of the Commander and eight senior Laboratory members, to make the decisions on where we will make an investment. Decisions are made within the limitations of the Laboratory's budget, manpower and facilities. Our planning process is shown in Figure 2. We take into account the "Big Picture" at the start of the process, assessing the Air Force needs for each of our major thrust areas. Resource allocations are issued for each of our technology clusters. We go through a process of internal competition at the cluster level evaluating ideas for new programs and also evaluating the on-going cluster levels of investment. We always demand of ourselves whether we have a valid rationale that answers, "What's in it for the Air Force?" We consider whether the program is answering a valid Air Force requirement or whether it is a fundamental effort that will exploit technology to achieve increased or new capabilities, such as efforts highlighted by Forecast II, etc. We realize that there are times when we should strive to extend technological boundaries, and we do invest in these areas, but we also don't do technology for technology's sake - we do it for the Air Force's sake. We do it because we believe that with this new technology it will find application in Air Force Systems of the future and, therefore, it is a good investment.

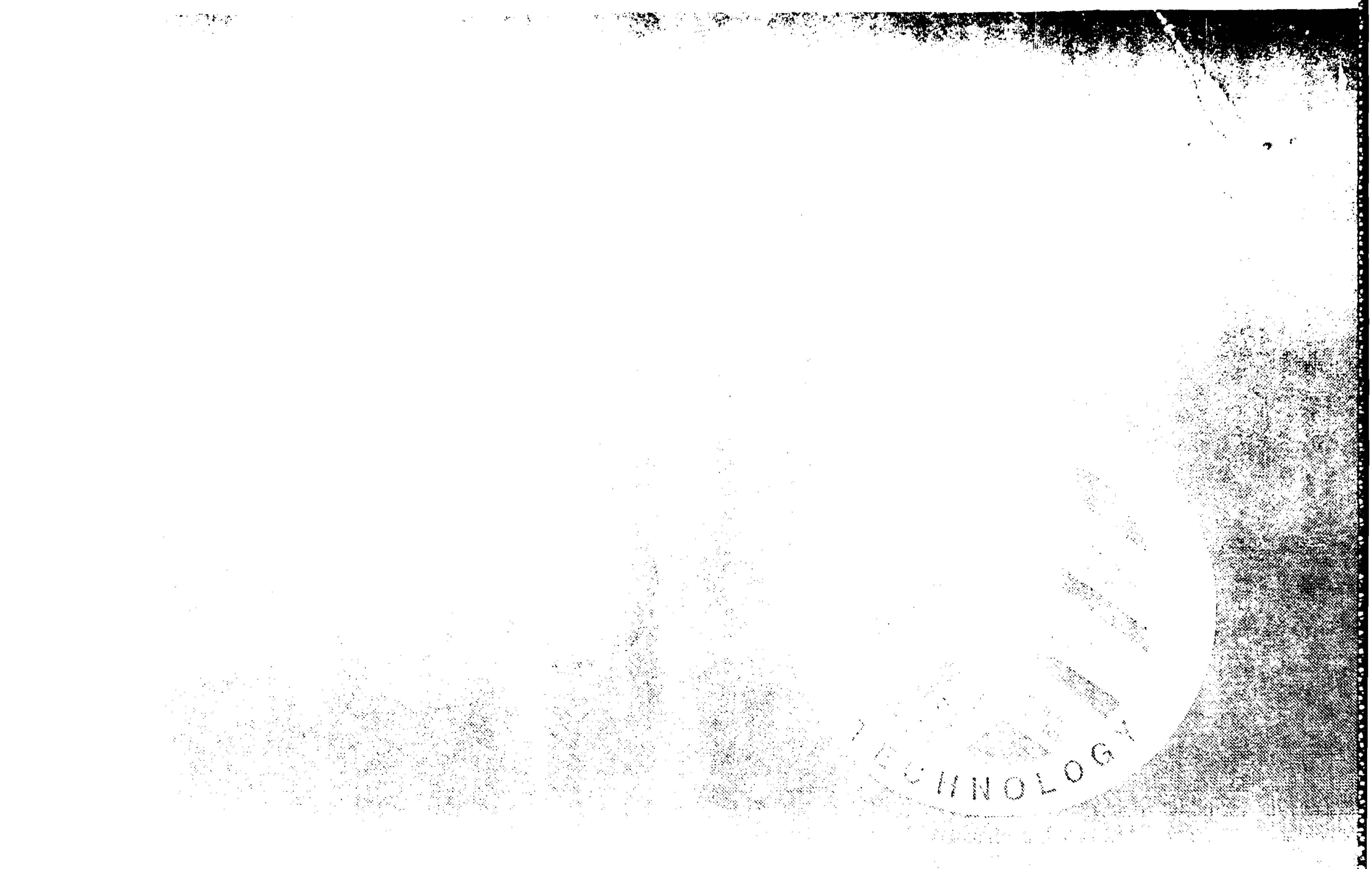


Figure 1.

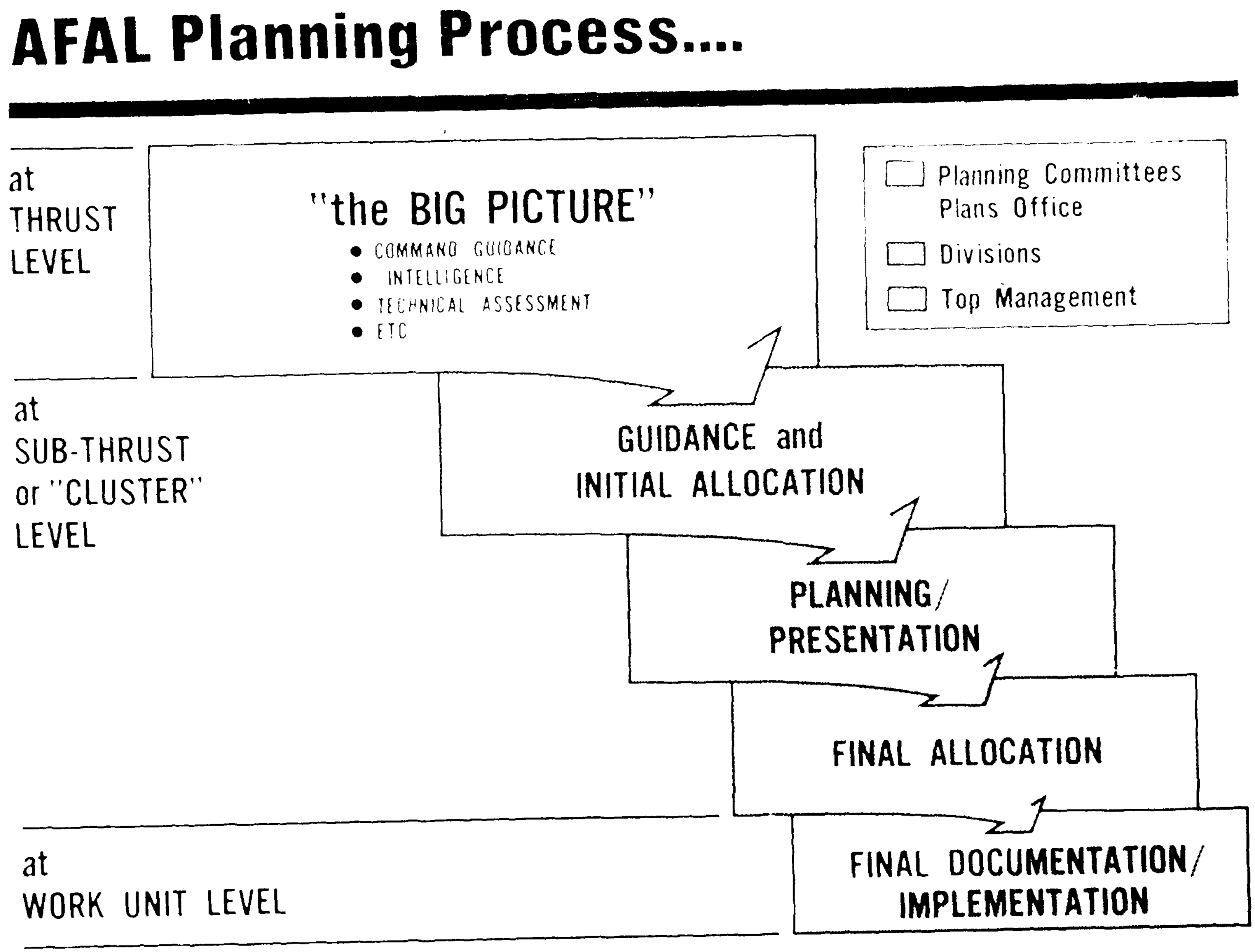

AFAL Planning Process....
at
THRUST
LEVEL
"the BIG PICTURE"
COMMAND GUIDANCE
INTELLIGENCE
TECHNICAL ASSESSMENT
ETC
Planning Committees
Plans Office
Divisions
Top Management
at
SUB-THRUST
or "CLUSTER"
LEVEL
GUIDANCE and
INITIAL ALLOCATION
PLANNING/
PRESENTATION
FINAL ALLOCATION
at
WORK UNIT LEVEL
FINAL DOCUMENTATION/
IMPLEMENTATION

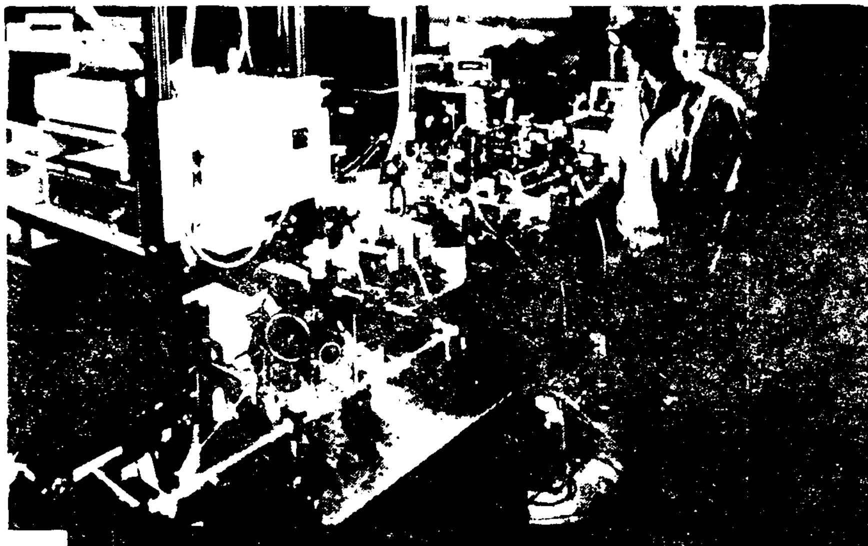
Figure 2.

The Air Force Astronautics Laboratory's program is organized into five Technical Thrusts: One for each of the three major rocket propulsion applications areas, i.e., ballistic missiles, air-launched missiles and space propulsion systems; one for fundamental technology which is (or will be) useable in several application areas; and one for non-propulsive space vehicle technologies space systems. The AFAL/AFOSR Basic Research (Program Element 61102F) program summary description is shown in Figure 3. The five Technical Thrusts are congruent with the five projects under the Laboratory's Exploratory Development Program Element (62302F). A summary of the 6.2 program is shown in Figure 4. Our Space and Missile Rocket Propulsion Advanced Technology Development (63302F) projects are aligned with our applications-oriented Technical Thrusts. A summary of the 6.3 program is shown in Figure 5.

A breakout of the exploratory development program to the subthrust, or cluster, level is shown in Figure 6. The area of the boxes is proportional to the amount of 62302F funds allocated for each cluster.

Technology development applicable to the Strategic Defense Initiative (SDI) is accomplished under the auspices of a separate SDI Technology Office. The focal points, and their respective areas of responsibility, within the SDI Technology Office are shown in Figure 7.

AFAL Basic Research....



OBJECTIVES

- Conduct Research in
  - New Energetic Compound Synthesis
  - CVD Process Variables for C/C
  - Fracture Mechanics
  - Energy Exchange Mechanisms
  - Chemical Kinetic Influences
  - Advanced Concepts
  - Excited States
  - Plasma Diagnostics
  - Space Structures Identification/Control

FUNDING (SM)

PE FY	87	88	89	90
61102F	2.5	2.3	2.6	2.4

PAYOFFS:

- Cleaner Design Alternatives
- Magnitude Gains in Usable Thrust
- New Knowledge for Technologies
- Peer Interactions with Lab S&E
- Transition Research Findings to 6.2 Dev.

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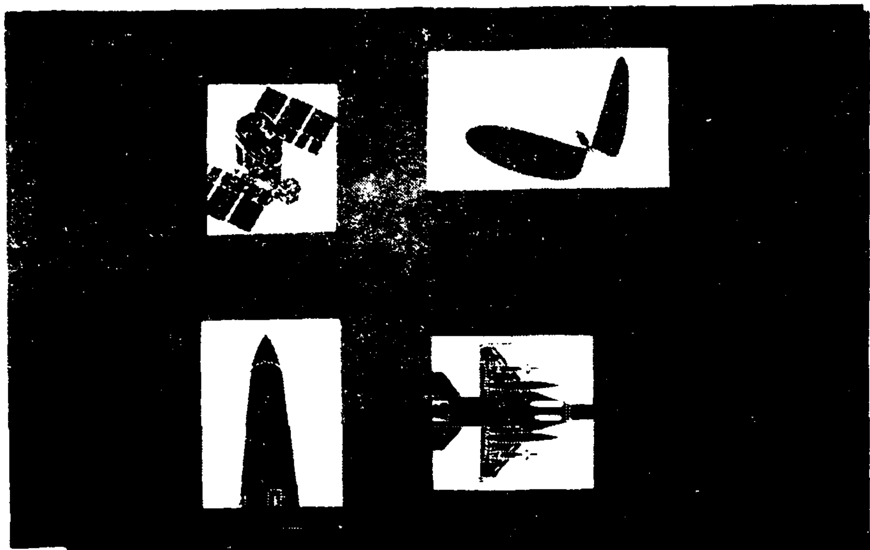
Figure 3.

Rocket Propulsion 62302F....



THRUSTS:
- Space Propulsion
- Space Vehicle Technologies
- Air-Launched Missile Propulsion
- Ballistic Missile Propulsion
- Fundamental Technologies

FUNDING ($ × Millions):*

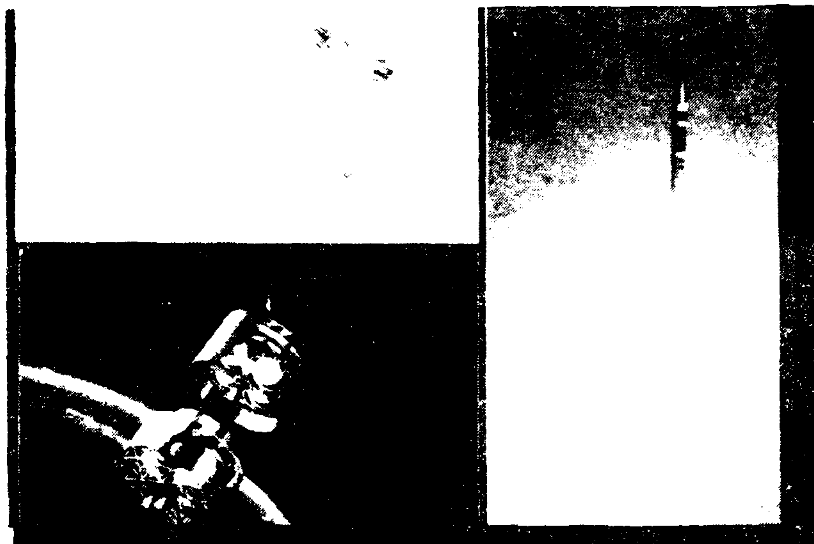
FY88	FY89	FY90
38.4	39.2	41.1

*FY89 PB

PAYOFFS:
- Assured Access to Space
- Enhanced A/L Mission Flexibility
- Reduced Observables
- Survivable/Flexible Basing Modes
- Lower Cost/Higher Reliability
- More Payload to GEO
- Enhanced Space Superiority

Figure 4.

Space & Missile Rocket Propulsion (PE63302F)....



OBJECTIVES

- Integrate/Demonstrate Advanced Rocket Propulsion Technology Options
- Increase Mission Capabilities for Tactical and Strategic Weapon and Space Systems
- Enhance "ilities" at Reduced Technical Risk and Cost

PROJECT/PROGRAMS

- Air-Launched Missile Propulsion (6339)
- Space Systems Propulsion (6340)
- Ballistic Missile Propulsion (6341)

PAYOFFS

- Air-Launched Technology
  - 50-100% A/C Weapons Loadout Increase
- Space Systems Technology
  - 45-280% Payload Increase to GEO Over IUS
  - 36% Length Reduction Over Centaur
  - 80% Cost Reduction Over IUS
- Ballistic Missile Technology
  - 18% Throw-Weight Increase Over SOTA

Figure 5.

AFAL Exploratory Development Program....

FY89 "President's Budget" -- Areas are Proportional to Funding Levels

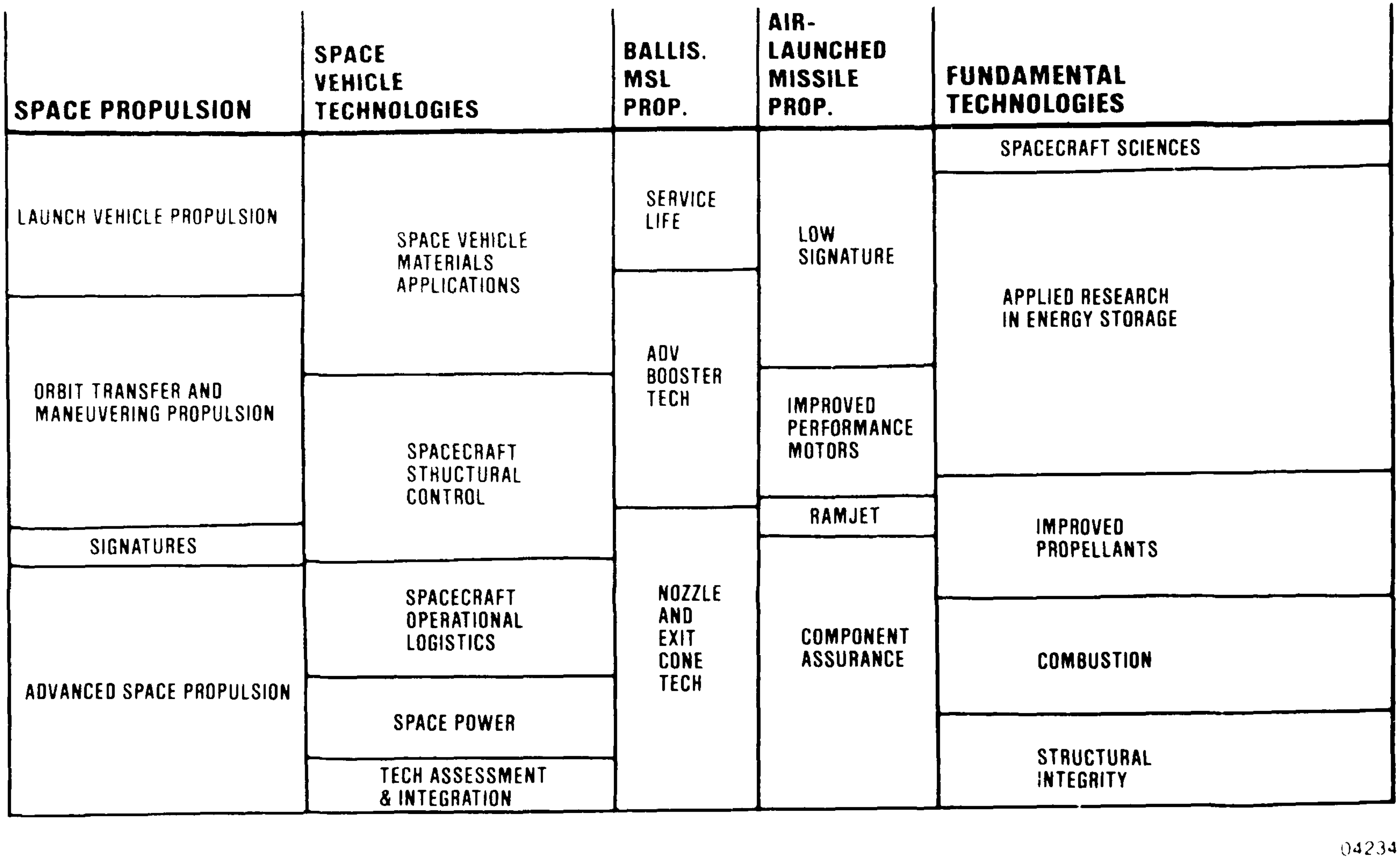


Figure 6.

AFAL SDI Technology Office....

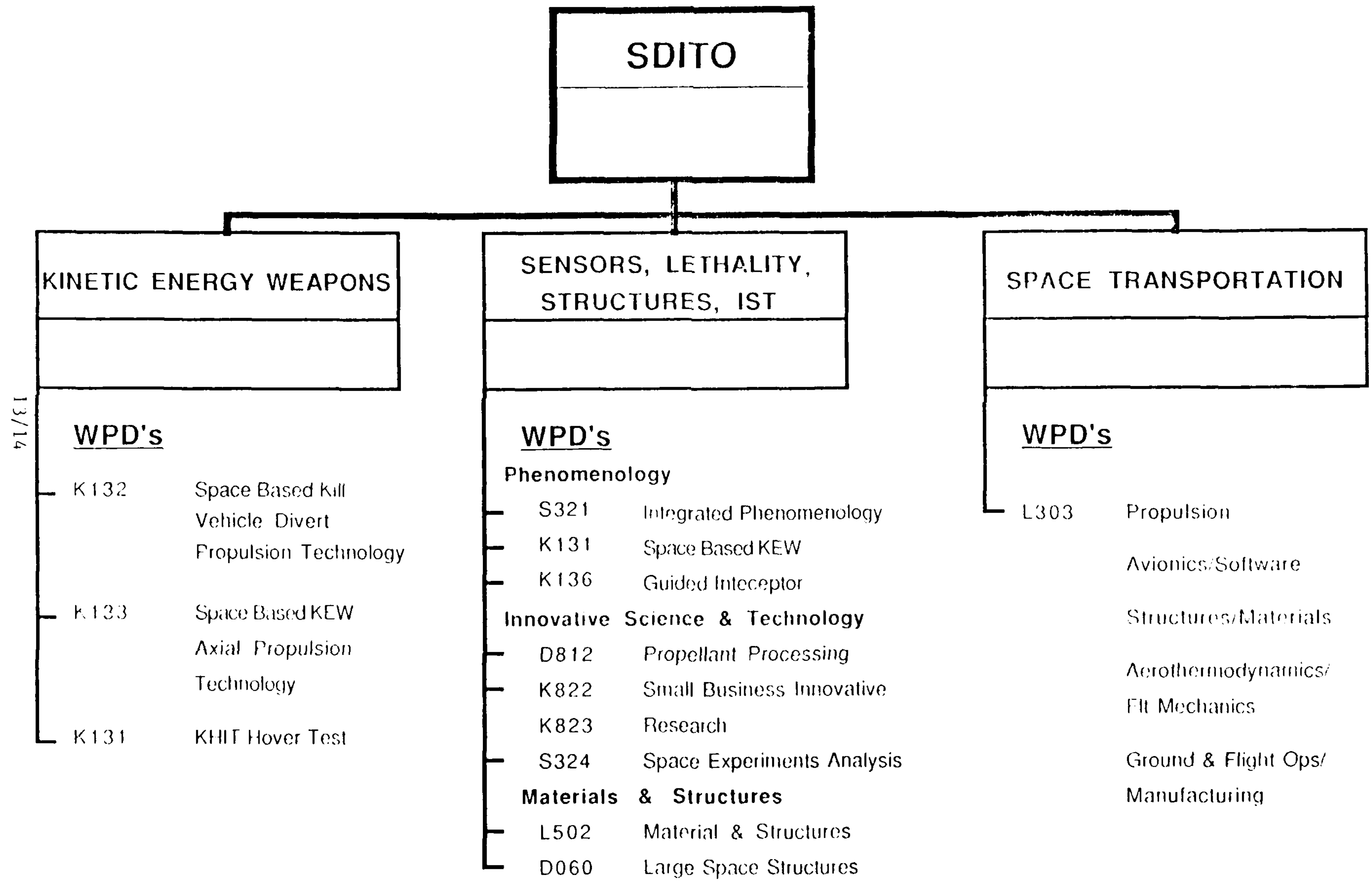


Figure 7.

TECHNOLOGY PROGRAMS

A discussion of each of the Laboratory's Technical Thrusts is provided in the following paragraphs. The Technical Thrusts will be discussed in the order shown in the upper right quadrant of Figure 4.

1. Space Systems Propulsion Technology

The Space Systems Propulsion Thrust provides technology for all future USAF space systems: launch vehicles, orbit transfer/maneuvering vehicles, and satellites. In addition, as in the past, technology from this thrust will be applied by the Navy, NASA and commercial industry to their space systems. This thrust is summarized and illustrated in Figures 8 through 12.

a. Objectives

The overall Space Systems Propulsion Technology Thrust is broken into the five clusters shown in Figure 8. Each of these clusters represents an area in which USAF requirements for advanced propulsion technology are being addressed. The efforts within the clusters are oriented toward achieving the overall thrust objectives shown in the upper right quadrant of Figure 8. The objectives of the various clusters include: (a) the transportation of larger, heavier payloads to orbit on a low cost, routine, and assured access to space basis through improved manufacturing and design utilizing advanced materials and engine concepts; (b) affordable space propulsion systems through improved performance, lighter weight and increased life orbit transfer and maneuvering capability; (c) advanced electric, solar, and radically new propulsion systems having high performance, long life, and increased thrust.

b. Clusters

The three major clusters shown in Figure 8 will be discussed, with the exception being Signatures.

(1) Launch Vehicle Propulsion

This cluster is summarized in Figure 9. The purpose of this cluster is to develop the propulsion technology needed to enable affordable fully reusable launch vehicles as well as low cost expendable or partially reusable vehicles. The required increases in the engine thrust/weight ratio and specific impulse to enable single stage to orbit will be achieved through innovative design approaches and application of advanced materials. Low cost for the expendable and partially reusable systems will be achieved through automated manufacturing as well as innovative design. There are technology areas unique to both liquid and solid propulsion which will focus on improved performance/reduced weight and reduced acquisition/operations cost for both types of propulsion. The major goals for liquid systems are to develop and demonstrate component technologies for an advanced liquid oxygen/liquid hydrogen engine which delivers high trajectory effective specific impulse while being light weight and having long operational life with minimum maintenance. Performance improvement and weight reduction will be achieved by the application of advanced materials. The major goals for solid systems are to reduce recurring costs for both expendable and recoverable boosters by developing nozzleless concepts.

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Space Systems Propulsion....

OBJECTIVE

- Develop and Demonstrate Technology to Improve
  - Performance
  - Lifetime
  - Survivability
  - At Lower Cost

CLUSTERS

- Launch Vehicle Propulsion
- Orbit Transfer and Maneuvering Propulsion
- Advanced Space Propulsion
- Signatures

PAYOFFS

- Assured Access to Space
- Reliable and Effective Space Operations
- Improved Survivability
- Affordable Space Systems

TR550

Figure 3.

Space Systems

Launch Vehicle Propulsion....

OBJECTIVES/GOALS

- Increase Reusability/Decrease Processing Time
- Increase Trajectory Effective ISP by 15 sec
- Increase Engine Thrust/Weight to 100:1
- Explore Innovative Designs

TECHNOLOGY/CHALLENGES

- Define Design Concepts and Technology Demonstrator for Advanced O_2/H_2 Engine
- Apply Advanced Materials and Fabrication Techniques
- Verify Low Cost Design and Manufacturing Approaches

PAYOFFS/MILITARY SIGNIFICANCE

- Allow Affordable Fully Reusable Two Stage Launch Vehicle
- Building Block for Single Stage to Orbit
- Reduce Cost of Expendable Launch Vehicle

Figure 9.

(2) Orbit Transfer and Maneuvering Propulsion

This cluster is summarized in Figure 10. The objective of the orbit transfer and maneuvering propulsion cluster is to develop and demonstrate the technology for advanced orbit transfer and maneuvering propulsion for future Air Force space applications. The projects in the cluster are grouped according to the three major type of propellants used: Storable Liquid Systems, which contains both Modular Storable and Advanced Maneuvering Propulsion, Cryogenic Liquid Systems and Solid Motor Propulsion.

The Storable Liquid Propulsion area is dedicated to a high performance pump fed NTO/MMH 3750 lbf engine and associated feed system. This engine is part of the Modular Storable subgroup since the engine and tank arrangements can be modified to customize the propulsion system for diverse mission requirements. The technology offers a 50 percent reduction in cost per pound for orbit transfer of large payloads to GEO and increased maneuvering capability of 40 percent over state-of-the-art pressure fed systems. This engine and feed system is also very compact and would be optimal for the integral propulsion systems of current Air Force interest. The other subgroup in the Storable Liquids area is Advanced Maneuvering Propulsion. This effort is dedicated to improving maneuvering capability for low thrust (10 to 100 lbf) maneuvering systems. The major work presently being done in this area is in long term oxidizer storability and its effect on feed system components.

The Cryogenic Liquid Systems area is directed toward the development of a compact feed system and a high performance LO2/LH2 500 lbf pump fed engine. The compact feed system uses a toroidal liquid oxygen tank to achieve a very short stage length. The resulting propulsion system using this tank will have an on-orbit storage capability of 30 days with a 36 percent reduction in stage length compared to the present Centaur stage. The low thrust cryo engine will provide a low acceleration delivery capability for large space structures.

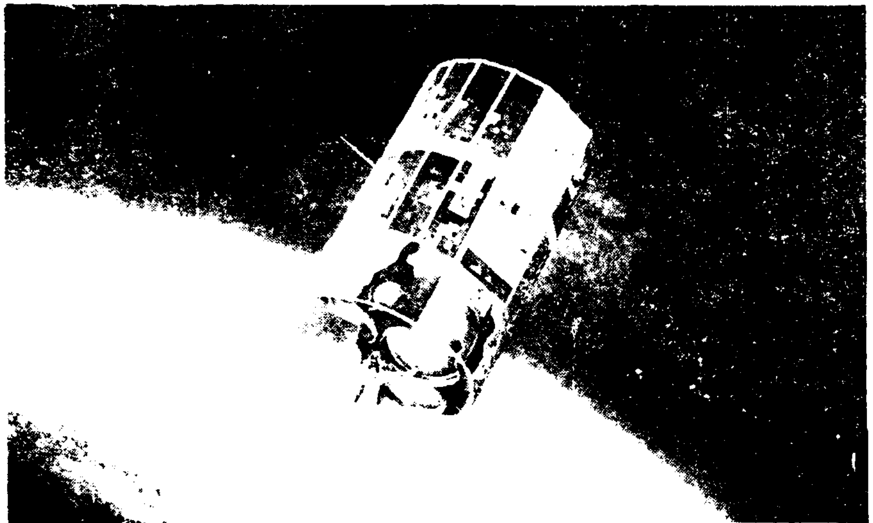
The Solid Motor Propulsion area has its primary emphasis on demonstrating space storage of solid rocket motors. Areas of investigation include radiation, temperature and vacuum effects over the long-term on solid propellants. The technology developed will allow the use of solid rocket motors for on-orbit storage and recall of satellites.

(3) Advanced Space Propulsion

This cluster is summarized in Figure 11. The Advanced Space Propulsion cluster pursues propulsion concepts that offer performance capabilities much greater than present chemical systems. Attaining specific impulses greater than 800 seconds and offering broad thrust ranges for a variety of mission applications are primary goals. These higher performance technologies increase payload capabilities while helping reduce operational costs. The cluster's primary emphasis is on electric and solar propulsion, and the identification of new advanced concepts.

In electric propulsion, the near-term emphasis is in arcjet propulsion. A 30kW ammonia arcjet advanced technology development (ATD) program just beginning will measure EMI and contamination in a 1993 space test. Contractual efforts are underway to develop advanced arcjet concepts, and work continues on an in-house arcjet research facility. Efforts in the area of magnetoplasmadynamic (MPD) thruster research

Orbit Transfer and Maneuvering Propulsion....



OBJECTIVES/GOALS

- Demonstrate Modular Storable Space Propulsion
- Demonstrate Cryogenic Orbital Transfer Propulsion
- Develop Advanced Maneuvering Propulsion
- Demonstrate Long Term Storage of Propellants

TECHNOLOGY/CHALLENGES

- Injector Stability and Performance
- Thrust Chamber Heat Transfer and Durability
- Turbomachinery Durability and Performance
- Tank and Feed System Fluid Dynamics
- Long Term Propellant

PAYOFFS/MILITARY SIGNIFICANCE

- Provide Low Cost Orbit Transfer (50% Cost Reduction)
- Optimize Upper Stages for New ELVs
- Increase Flexibility (Multistart, Storage on Orbit, 40% Increase of Maneuverability)
- Increase Survivability (Maneuverability, Storage)
- Provide Low Thrust Transfer Capability (.05-0.2g)

TR598a

Figure 10.

Space Systems

Advanced Space Propulsion....

OBJECTIVES/GOALS

- Develop Reduced-Cost High Performance Advanced Orbit Transfer and Maneuvering Propulsion
  - Electric Propulsion
  - Solar Propulsion
- Identify and Evaluate Revolutionary Space Propulsion

TECHNOLOGY/CHALLENGES

- High Performance ($I_{SP} > 800$ sec)
- Long Life/Reliability
- High Efficiency

PAYOFFS/MILITARY SIGNIFICANCE

- Reduces Cost of Current Missions
- Enables New Missions
- Increase Payload Mass to GEO Capability (Twice that of Chemical)

Figure 11.

continue with an in-house effort to characterize pulsed thruster performance. Steady state MPD development is being funded at the University of Stuttgart in West Germany, with in-house steady state work contemplated in the near future. In FY 89, research will begin on the pulsed electro thermal engine (PETE). This device promises to develop 1500 sec Isp at 60 percent efficiency using water as a propellant. Out year efforts include consideration of Hall type thrusters.

In solar propulsion, parallel technology developments of thrusters and concentrators continue. In the thruster area, in-house testing and evaluation of the one-pound, 800 sec Isp rhenium will be completed this year. Work on a second generation, heat exchanger-type thruster is expected to begin late next year. The last phase of thruster research will explore a directly heated gas concept labeled the volumetric absorber. Fundamental chemistry research on this alkali metal seeded hydrogen gas thruster is nearing completion in the AFAL's unique high temperature (2,000 K) and pressure (up to 100 atm) cell. In the concentrator area, work continues on light (.4 kg/kW), inflatable, off-axis, parabolic mirrors. Fabrication and optical accuracy testing of 10,000 to 1 concentration ratio mirrors in the 10 meter class is underway, with a concentrator flight test planned for the early 1990's.

The cluster's Future Technology explorations have led to a number of non-conventional propulsion concepts being adopted for research by the AFAL. Recent advanced concepts investigations have identified fusion propulsion as the next major area to be evaluated for applicability to Air Force propulsion needs.

c. Payoffs

Figures 8, 9, 10, and 11 show some of the payoffs that can be realized through the application of rocket propulsion technology to future Air Force space systems. Figure 12 lists representative systems to which the technologies in this thrust can transition. There are many technologies involved, from advanced engines to thermal analysis for cryogenically-fueled OTVs, to gas dynamics and radiation physics for exhaust plume signature characterization.

d. Funding

Table 1 shows the total funding that we plan to devote to the Space Systems Propulsion Technology Thrust through FY 90. Program Element 61102F is AFOSR Research, Program Element 62302F is for Exploratory Development, and Program Element 63302F is for Advanced Technology Development.

TABLE 1. Space Systems Propulsion Funding ($K)

PROGRAM ELEMENT	FY 88	FY 89	FY 90
61102F	-	237	210
62302F	5,966	4,125	4,050
63302F	3,283	4,595	6,515

Space Systems Propulsion

Transition Targets....

- Advanced Launch Vehicles
  - SSTO, Low Cost Expendable, HLLV
- Satellite Systems
  - Defense Support Program (Advanced)
  - Global Positioning System (Block II, III; Advanced)
  - Defense Meteorological Satellite Program (-3; Advanced)
  - Defense Satellite Communications System (Advanced)
  - Milstar (Block Change)
  - Satellite Data System (Block Change)
  - Wide Area Surveillance Program (Block Change)

TR333

Figure 12.

Space Systems Propulsion

Transition Targets, (Cont'd)....

- Advanced Upper Stage Function
  - Imbedded Propulsion
  - Orbit Transfer Vehicles (Expendable/Reusable)

- Forecast II
  - Advanced Heavy Lift Space Vehicle (PS-24)
  - Space-based Reusable Orbit Transfer Vehicle (PS-28)
  - All Systems Requiring Orbit Transfer

Figure 12 (continued).

e. Future Plans

Planned future areas of work within the Space Systems Propulsion Technology Thrust are listed in Figures 13 through 15.

2. Space Vehicle Technologies

The Space Vehicle Technologies thrust provides the integration of key propulsion and nonpropulsion disciplines necessary to develop enabling technology for future Air Force space systems. This technology is being developed in the following sub-thrusts: space vehicle materials applications, spacecraft structural control, spacecraft operational logistics, space power, and technology assessment and integration. This thrust is illustrated and summarized in Figures 16 through 20.

a. Objectives

As shown in Figure 16, the intent of this thrust is to provide advanced technologies which will allow the U.S. to do a great many more things in space and to do these things at lower cost and free of obstruction from aggressive enemy action. The objectives of the various clusters include: applying advanced materials to space vehicles; developing control technologies for precision space structures; developing advanced spacecraft power and thermal management technologies; developing propellant management, servicing, and resupply technology; and the identification and development of critical spacecraft integration technologies.

The technologies being pursued will provide significant payoff to the survivability and affordability of future Air Force space systems. For example, the use of advanced materials and control techniques could provide future spacecraft with up to a 50 percent weight savings over today's approaches. This could enable a new class of space structure for advanced missions.

b. Clusters

The three major clusters shown in Figure 8 will be discussed, with the exceptions being Space Power and Technology Assessment and Integration.

(1) Space Vehicle Materials Applications

The Space Vehicle Materials Applications program is directed toward expanding the AFAL's role in the Space Vehicles Technology area. The challenges addressed are as shown in Figure 17. The projects chosen were based on USAF needs for lightweight, dimensionally-stable, controllable spacecraft structures, and lower launch costs. They were also chosen because they represent extension and transition of technologies and in-house capabilities developed for rocket propulsion application. Thus, the advanced spacecraft structures area was selected as the major emphasis for this cluster. We recognize that the Flight Dynamics and Materials Laboratories have efforts in this area as does NASA. We continue to work with these organizations to ensure that our work does not duplicate but complements and extends their efforts. We are aiming at taking advantage of advancements in both aircraft and rocket structures and applying them to spacecraft structures.

A1238-C09

Space Systems

Launch Vehicle Propulsion....

TECHNOLOGY PROGRAM PLAN FY88-93

- Advanced O_2/H_2 Engine
- Advanced Materials
- Low Cost Solid Motor

TR592

Figure 13.

A1238-C19

Space Systems

Orbit Transfer & Maneuvering Propulsion....

TECHNICAL PROGRAM PLAN
FY88-93

- **Storable Liquid Systems**
  - **Modular Storable Space Propulsion (N_2O_4/MMH)**
    - **XLR-132 Engine (3750 lbf Thrust)**
    - **Feed System**
    - **High Thrust, High Performance Injector Demo**
  - **Advanced Maneuvering Propulsion**
- **Cryogenic Liquid Systems (O_2/H_2)**
    - **Compact Cryogenic Feed System**
    - **XLR-134 Engine**
- **Solid Motor Propulsion**

TR600

Figure 14.

A1238-C29

Space Systems

Advanced Space Propulsion....

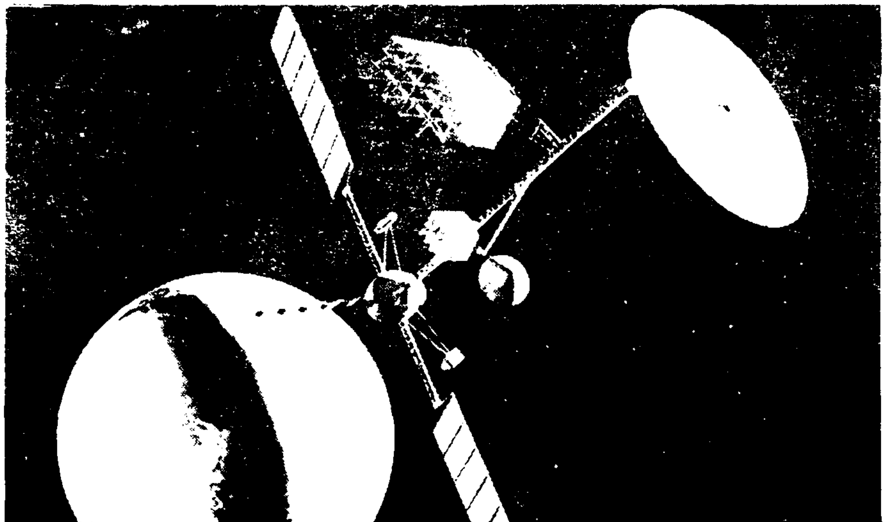
TECHNOLOGY PROGRAM PLAN FY89-93

- Electric Propulsion
  - Initiate Arcjet ATD
  - Investigate Pulsed Electro Thermal Engine
  - Complete In-House Arcjet Facility Construction
- Solar Propulsion
  - Conduct Next Generation Thruster Research
  - Flight Test Inflatable Concentrator

TR617

Figure 15.

Space Vehicle Technologies....



OBJECTIVE

- Provide Technology Necessary For:
  - Survivability
  - Affordable Space Systems
  - Lower Integration Risk

CLUSTERS

- Space Vehicle Materials Applications
- Spacecraft Structural Control
- Spacecraft Operational Logistics
- Space Power
- Technology Assessment and Integration

PAYOFFS

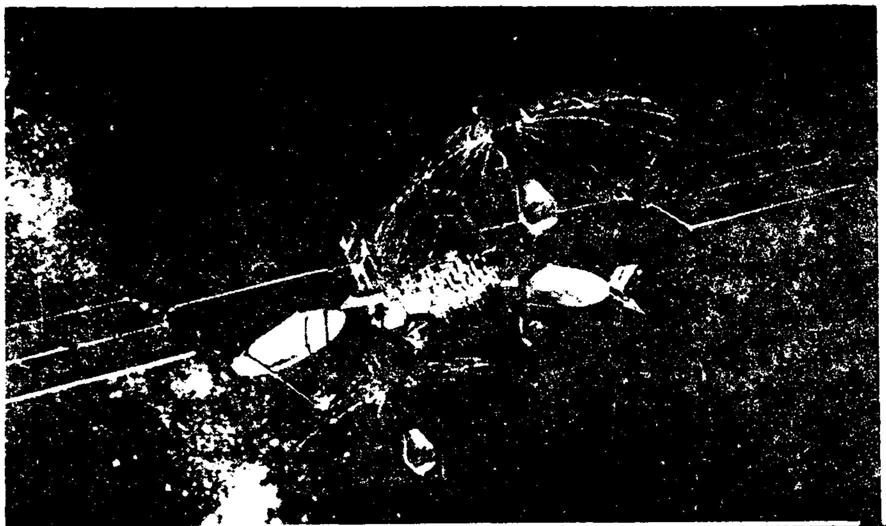
- Improved Survivability
- Lower Cost Space Operations
- Enhanced Space Superiority

TR345

Figure 16.

A1238-E18

Space Vehicle Materials Applications....



OBJECTIVES/GOALS

- Demonstrate Advanced Spacecraft Structural Technology
- Apply Advanced Composite Materials to Spacecraft and Launch Vehicles
- Develop Technology for Imbedding Sensors and Actuators
- Reduce Production and Launch Costs

TECHNOLOGY/CHALLENGES

- Adapt Advanced Composite Materials and Structural Design Concepts to Spacecraft
- Develop Intelligent Spacecraft Structures
- Adapt Advanced Composite and Fabrication Technology to Payload Shrouds

PAYOFFS/MILITARY SIGNIFICANCE

- Reduce Spacecraft Structure Weight by 50%
- Close Tolerance Control of Spacecraft Structures
- Reduce Payload Shroud Cost/Weight by > 20%

TR604

Figure 17.

Our work in composites for spacecraft structures initially concentrates on the applications of composite materials to structures which require light weight coupled with high stiffness and minimal outgassing on orbit. Analysis, fabrication, and testing being done in-house as well as on contract. We are also exploring the application of composites to large booster payload shrouds. We will extend the thin film technology work done for other applications to structures which can be made in space. This can provide a means of transporting the structural material as a liquid which can be relatively compact and dense, and forming it into a very lightweight structure in space. Smart structures employing embedded sensors and actuators to provide control and/or health assessment of spacecraft structures will be developed. Coatings and adhesives will be developed to provide longer life and more reliable structures which will be easier to repair in space.

(2) Spacecraft Structural Control

In Spacecraft Structural Control, we are working on technologies to enable future USAF space systems. The challenges are as shown in Figure 18. Several proposed space systems will suffer performance degradation caused by environmental disturbances and interaction between the spacecraft structure and the spacecraft control system; we must demonstrate that structural vibrations caused by these interactions can be controlled, and that precise structural shapes and positions can be maintained in the presence of disturbances. Methods available for controlling structures generally require many sensors and actuators and large amounts of computer power; we need to minimize these requirements. Developing structural control technologies often entails performing experiments; finding ways to make structures behave in the presence of gravity as they do in the weightlessness of space is another of the challenges we face. To meet these challenges, we have set the goals shown.

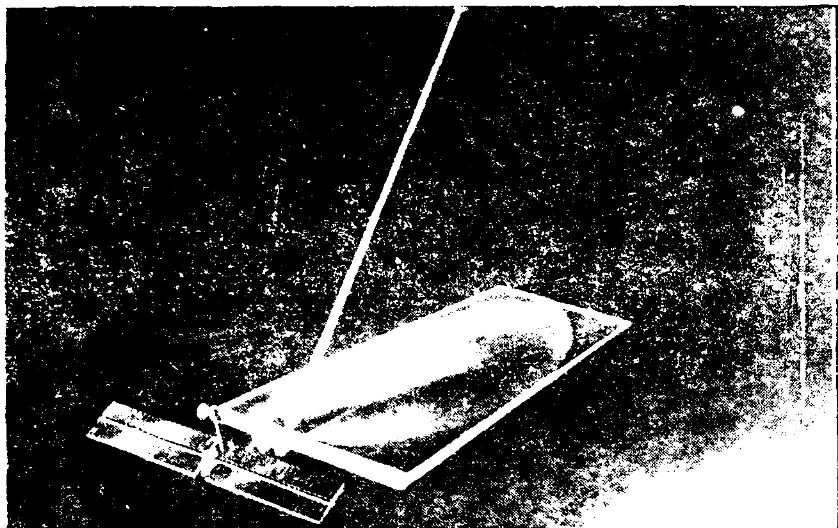
We will develop new methods for modeling and controlling precision structures. We will continue establishing ground facilities and developing experimental techniques to demonstrate structural control technologies. We will build upon our already completed work in the Flexing Structure Control Lab, in the Antenna Shape Control testbed, and in our in-house labs to demonstrate modeling, identification, and control of precision space structures. Achieving these goals enables the payoffs shown.

Accurate sending and reliable control of vibrations, shape and position will enable large space structures such as those envisioned for space-based surveillance and space-based defense. For some spacecraft, implementation of active structural control will reduce the structural mass by as much as 50 percent. New experimentation techniques will reduce the number of expensive space experiments necessary to effectively demonstrate new structural control technologies. Lower weight and less expensive technology demonstrations point to lower cost space systems for the Air Force.

(3) Spacecraft Operational Logistics

The spacecraft operational logistics cluster covers technology developments in the areas of long-term cryogenic storage and fluid management in space. These technologies are summarized in Figure 19. The overall goal of the cluster is to enhance space system on-orbit operational capability and service life.

Spacecraft Structural Control....



OBJECTIVES/GOALS

- Develop Control Technologies for Precision Space Structures
- Establish Facilities to Demonstrate Structural Control Technologies
- Demonstrate Modeling, Identification and Control of Precision Space Structures

TECHNOLOGY/CHALLENGES

- Distinguishing and Controlling Structural Modes
- Minimizing Computation and Instrumentation Requirements
- Demonstrating Space Structure Control Technologies

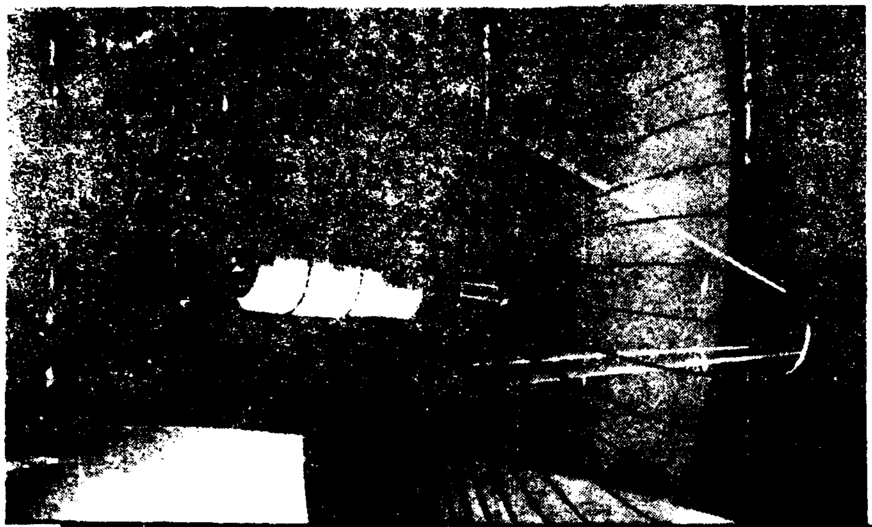
PAYOFFS/MILITARY SIGNIFICANCE

- Enable a New Class of Space Structures
- Up to 50% Weight Reduction for Some Spacecraft
- Reduce Risk for Space Based Radar
- Reduce Cost of Demonstrating Control Technologies

Figure 18.

Space Vehicle Technologies

Spacecraft Operational Logistics....



OBJECTIVES/GOALS

- Enhance In-Space Cryogenic Storage Capability and Survivability
- Develop Space System Propellant Management, Servicing, and Resupply Technology
- Reduce Ground Support Complexity for Cryogenic Systems

TECHNOLOGY/CHALLENGES

- High Performance Cryogenic Thermal Control Elements for Large Systems
- Eliminate Ground Purge of Cryogenic Systems
- Provide Lightweight Cryogenic System Protection
- On-Orbit Servicing without System Degradation

PAYOFFS/MILITARY SIGNIFICANCE

- Improve Operational Flexibility
- Extend On-Orbit Life for Cryogenic & Storable Fluid Systems
- Reduce Space System Replacement Requirements and Costs

Figure 19.

The long-term cryogenic storage technology development is the main focus of the cluster. The current program plan focuses on passive thermal control to meet the in-space storage requirements. Key technologies include thick multilayer insulation blanket, thermodynamic vent systems, and low heat leak structural supports. These are being aggressively pursued. Emerging technologies, such as survivable lightweight outer shield and integrated active-passive cryogenic thermal control systems, also are being planned for development and demonstration in the early 1990's. To meet the expanded responsibility for astronautics technology, the AFAL will emphasize conducting cryogenic storage technology demonstration programs in-house while coordinating key technology developments through joint government-contractor efforts.

Under the fluid management area, the lab will concentrate on fluid dynamics control and space system propellant venting and resupply. A space flight experiment waiting to be launched aboard a Space Shuttle will evaluate the in-space performance of the propellant acquisition, pressurization, and fluid dynamics control systems of a toroidal tank. The demonstrated performance data will be used in the development of a high performance, compact cryogenic propulsion system for transferring space assets to higher orbits. Flight type system venting components will also be fabricated and performance demonstrated to transition the technology to the user community. The goal is to demonstrate flight type components prior to applying the technology to resupply system designs or missions.

c. Payoffs

Figures 16, 17, 18, and 19 show some of the payoffs that can be realized through the application of the space vehicle technologies of this thrust area. Figure 20 lists representative systems to which the technologies of this thrust could transition. Many of the technologies are high risk, high payoff areas. However, without these technologies, many of the complex future systems that are projected today will not be possible. Their advancement will require the participation of a broad spectrum of government and industry organizations and people.

d. Funding

Table 2 shows the total funding for this thrust through FY 90. Program Element 62302F is for Exploratory Development.

e. Future Plans

Planned future areas of work within the Space Vehicle Technologies Thrust are listed in Figures 21 through 23.

TABLE 2. Space Vehicle Technology Funding ($K)

PROGRAM ELEMENT	FY 88	FY 89	FY 90
62302F	3,770	4,290	4,540

A1238-E06

Space Vehicle Technologies

Transition Targets....

- Satellite Systems
  - Defense Support Program (Advanced)
  - Global Positioning System (Block II, III; Advanced)
  - Defense Meteorological Satellite Program (-3; Advanced)
  - Defense Satellite Communications System (Advanced)
  - Milstar (Block Change)
  - Satellite Data System (Block Change)
  - Wide Area Surveillance Program (Start-Up; Block Change)
  - Advanced Surveillance, Radar Systems
- Antisatellite Systems (Space-based)
- Reusable Orbit Transfer Vehicles

TR347

Figure 20.

A1238-E07

Space Vehicle Technologies

Transition Targets, (Cont'd)....

- Forecast II
  - Space-based ASAT System (PS-25)
  - Manned Space Station (PS-27)
  - Space-based Reusable Orbit Transfer Vehicle (PS-28)
  - Space-based Space Surveillance (PS-32)
  - Space Power (PT-5)
  - Adaptive Control of Ultra-Large Arrays (PT-15)
  - Satellite Protection (PT-19)

TR34A

Figure 20 (continued).

A1238-E23

Space Vehicle Technologies

Space Vehicle Materials Applications....

TECHNOLOGY PROGRAM PLAN FY88-93

- Composite Material Processing for Space Applications
- Composite Joining Technology
- Application of Composites to:
  - Space Structures
  - Payload Shrouds
- Embedded Sensors and Actuators
- NDE of Composite Space Structures

TR606

Figure 21.

Space Vehicles

Spacecraft Structural Control....

TECHNOLOGY PROGRAM PLAN FY88—93

- Demonstrate Systems Identification, Slewing and Vibration Suppression Technologies on ASTREX
- Develop Micro-Gravity Facility and Begin Ground Experiments in Spacecraft Structural Control
- Identify Detailed Structural Performance Requirements for Several Proposed Spacecraft, Including Space Based Radar
- Develop Advanced Sensors and Actuators for Spacecraft Structural Control
- Demonstrate Shape Sensing and Control of a Lightweight Antenna Structure
- Investigate Technologies to Reduce Cost and Weight of Future Air Force Spacecraft

Figure 22.

Space Vehicle Technologies

Spacecraft Operational Logistics....

TECHNOLOGY PLAN
FY88-94

- Long Term Cryogenic Storage
- Space Flight Fluid Management Experiments
- Venting Component Technology Demonstration

Figure 23.

3. Air-Launched Missile Propulsion Technology

The Air-Launched Missile Propulsion thrust develops the propulsion technology needed for air-to-air and air-to-surface missiles. This technology will provide future missile systems with the following benefits: increased survivability, increased lethality, increased reliability, increased age life, and increased cost effectiveness. The principal areas of emphasis are understanding and manipulating plume signatures, improving performance and providing energy management. Technology from this thrust has also been adapted by the Navy and Army in their tactical missiles. This thrust is illustrated and summarized in Figures 24-26.

a. Objectives

The overall objectives of this thrust are presented in Figure 24. The operational benefits being provided in signature, survivability, range, and fire power are necessary in order to overcome the numerical superiority and increased threat our forces are facing. By reducing our missile signatures (infrared, ultraviolet, visible and radar) and improving missile performance we will increase missile flexibility and lethality. These missile improvements equate to increases in aircraft survivability and mission performance (e.g., more munitions on target, more kills per pass, higher sortie rates, etc.). As the above operational benefits are being provided, it is also a major objective to provide logistics benefits in reliability, age life and costs. The work in this thrust is performed under four subthrusts or clusters as outlined in Figure 24.

b. Clusters

The first cluster involves "Low Signature Motors." This cluster addresses low signature propellant development and plume analysis for air-launch systems. The objectives are to predict, analyze and minimize plume signatures, to improve the performance and reduce the costs and hazards of minimum signature propellants, and to establish meaningful hazards criteria for determination of detonable/nondetonable propellants. As missile airframes become "stealthier," the radar cross section (RCS) of the plume plays a greater role in enemy detection of the missile. To enable prediction and advantageous manipulation of the plume RCS, measurements need to be accomplished to validate RCS codes. Thus, the missile's kill probability is enhanced, as is the launching aircraft's survivability. Currently, minimum smoke propellants are more hazardous than reduced smoke propellants. However, minimum smoke propellant contrails are not visible below 27,000 feet in the European theatre, while reduced smoke propellant contrails are visible 50 percent of the time below 20,000 feet in the same theatre. A solid rocket motor may have a propellant web thickness greater than the propellant's critical diameter (that diameter which will support a steady-state detonation), be Class 1.3 by the Naval Ordnance Laboratory's card gap test, and yet have the propensity to detonate. An ability to clearly distinguish detonable/nondetonable propellants is greatly needed and will improve safety of handling and use of missiles. It will also aid in the determination of numbers of missiles to be stored near the launching aircraft and will enhance joint service weapons deployment and NATO theater use of advanced weapons. Technology areas being investigated to provide improved plume prediction and analysis are experimental acquisition of plume radar cross section, particulate, and shock structure data to validate and upgrade existing plume computer codes. Technology areas being investigated to improve the performance and reduce the hazards of minimum signature propellants are the development of propellants capable of operating at high pressures, and demonstration of propellants possessing Class 1.3 hazards classification.

Air Launched Missile Propulsion....

OBJECTIVES/GOALS

- Reduce Plume Detectability by 2/3
- Increase Medium Range F-Pole by 50%
- Increase Air-to-Surface Standoff by 100%
- Demonstrate Better than 15 year Service Life
- Maintain 95% Reliability with 90% Confidence
- Lower Costs by 50%
- Increase End-Game Velocity by 100%

CLUSTERS

- Low Signature Propellants
- Improved Performance Motors
- Technology for Ramjets
- Component Assurance

PAYOFFS/MILITARY SIGNIFICANCE

- Increased Probability of Kill
- Enhanced Launch Platform Survivability
- Simplified Logistics
- Reduced Costs
- Increased Mission Flexibility/ Multimission Capability

TR680

Figure 24.

The goal of the second cluster "Improved Performance Motors" is to investigate and develop new technologies, or optimize the use of current technologies, in order to improve the performance of motors for air-launched missiles. The programs in this cluster will result in motors with more efficient propulsion packaging than the current state-of-the-art, improved aerodynamic performance, an order of magnitude reduction in observables, and increased overall motor performance. As a bottom line, this means more missile range for less motor weight as well as increased survivability and lethality of the missile.

Future air-launched missiles such as those mentioned in Project Forecast II and the Aerospace Defense Initiative may have propulsion requirements well beyond current capabilities. In an effort to look for the revolutionary performance improvements which may be needed to perform some of these missions we have begun looking at Advanced Propulsion Concepts for Air Launch. Ignition of tactical motors must be reproducible and highly reliable, and the shock of ignition must not damage the motor's propellant. We have programs to develop low shock igniters. This cluster also includes projects to integrate these emerging component technologies into high performance motors as part of its advanced technology development, including the "High Performance/Low Observable Motor," and the "Future Missile Motor."

The third cluster is support "Technology for Ramjets." Responsibility for the development of ramjets lies within the Aero Propulsion Laboratory. However, ramjet operations depend upon solid rocket boosters to provide initial missile acceleration before ramjet takeover. It is the goal of this cluster to provide improvements in solid rocket technologies and the interfaces between the rocket and ramjet components. A short term goal is to reduce the booster volume while maintaining or improving the thrust level. This is being accomplished through the development of nozzleless boosters, increased performance propellant, and improved insulation.

The fourth cluster is "Component Assurance." The purpose of this cluster is to ensure that major new components under development can function reliably in the harsh air-launched environment. We also investigate ways to reduce cost so that advanced rocket motors can more readily be integrated into full-up systems. The programs in this cluster emphasize the "ilities," and successful completion of the programs will increase missile systems availability and reliability and could lead to longer service life. Since use of advanced composite materials can reduce rocket motor case weight by up to 40 percent over metal cases, we are studying the applicability of these materials to the air-launched environment. We are designing and building composite cases that will survive the air-launched captive carry and eject loads. We are also studying the effects of damage to composites that may be caused by in-process and field handling. We are integrating composite cases and other advanced technologies and demonstrating them in Advanced Technology Development programs. We've also successfully demonstrated the "Laser Initiated Arm/Fire Device," which uses fiber optics and lasers to provide safer, more reliable safing, arming, and firing of tactical rocket motors. We have successfully transitioned laser ignition and arm/fire devices to industry where they have been demonstrated in numerous tactical systems. It is important to accurately predict the useful lifetime of rocket motors in order to minimize logistics and surveillance requirements; our programs address this need. We are increasing our prediction and surveillance efforts on AMRAAM and SPARROW. We plan to initiate programs to identify low cost processing techniques and to integrate low cost components into complete rocket motors.

c. Payoffs

Specific payoffs available from air-launched missile propulsion are summarized in Figure 24. The increase in loadout is very important for more missiles per sortie. This will be achieved with reduction/elimination of fin controls; development of thrust vector controls will negate the necessity for large fins. Decreased signatures result from advances in propellant formulation technology. In addition, the component assurance area will result in greater reliability, maintainability and lower O/M costs.

All of the above technology advances need to be demonstrated in flight tests. A joint AFATL-AFAL-AFWAL program is designed to do this and is shown in Transition Targets (Figure 25). This is a very important program for all future air-launched systems. The modular features of the Advanced Missile Technology Integration (AMTI) test bed allow new components to be tested alone or in combination with other new components. In the rocket propulsion area, the leading edge technology to be tested in AMTI Phase I will be motors with a two-pulse capability to validate serviceability. Propulsion technologies for Phase II AMTI will include 1.3 minimum smoke propellant, advanced TVC, laser initiated AFD, filament wound graphite composite case with high temperature resins capable of 2,000 psi operating pressures, multi-dimensional carbon-carbon integral throat entry nozzle, and optimal energy management logic. These technologies are the forerunners of spectacular gains that will be achieved in future air-launched missile systems, many of which have been identified in FORECAST II.

d. Funding

Total funds to be expended in the Air-Launched Missile Propulsion Technology thrust from FY 88 through FY 90 are shown in Table 3. Program element 62302F is for the exploratory development efforts under Project 3148. Program Element 63302F covers the completion of an Advanced Technology Development (ATD) effort under Project 6339 to demonstrate advanced technologies in pulse motors, thermal barriers and composite cases. Also included in the 63302F area is the start an effort directed toward future air-launched missiles that will be integrated into the Phase II AMTI program. The 62203F effort is all the work supporting ramjet booster propulsion. Other funds are received to support ongoing system developments such as AGM-130, SRAM-II, CREST, and Hardened Target Weapon (HTW).

TABLE 3. Air-Launched Missile Propulsion Funding

		($K)	
PROGRAM ELEMENT	FY 88	FY 89	FY 90
62302F	2,336	2,330	2,200
63302F	700	2,100	2,320
62203F	190	150	-
63601F HTW	4	4	4
64322F AGM-130	13	9	-
63231F CREST	3	5	5
63364F SRAM II	40.5	61	-

A1238-B6

Air Launched Missile Propulsion....

TRANSITION TARGETS

- To SRAM II:
  - Service Life Methodology
  - Composite Motor Case
  - Tandem Radial Pulse Motor
  - Dynamic Load Test Facility
- To AMRAAM P^3I and AMTI
  - 3-Pulse Motor
  - Improved Propellant
  - Tactical Thrust Vector Control
  - Laser Arm/Fire Device
- To AFWAL/PO's Variable Flow Ducted Rocket (VFDR)
  - Simplified Ignition Scheme
  - Improved Rocket Booster

TR684

Figure 25.

Air-Launched Missile Propulsion

Low Signature....

TECHNOLOGY PROGRAM PLAN FY89-93

- **Low Observable Insensitive Propellant Development/Demonstration**
- **Low Observable, Detonation Mitigating Case/Bond System**
- **Plume Measurement/Prediction**

TR696

Figure 26.

Air-Launched Missile Propulsion

Improved Performance Motors....

TECHNOLOGY PROGRAM PLAN FY88-93

- Tactical Motor Demonstration (IH)
- Low Shock Igniter Evaluation
- Advanced Propulsion Concepts for Air-Launch
- Thrust Controllability

TR687

Figure 27.

A-1238-B31

Air-Launched Missile Propulsion

Component Assurance....

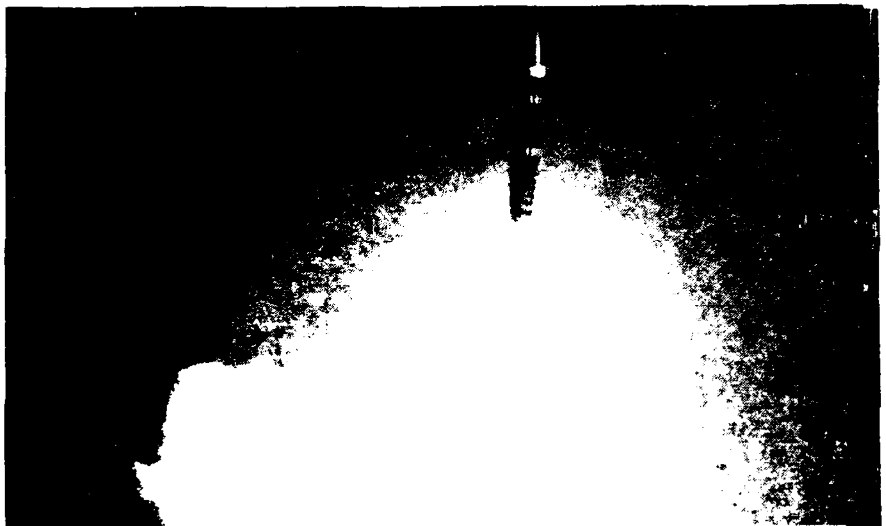
TECHNOLOGY PROGRAM PLAN FY88-93

- Composite Case Durability Investigation
- Damage Assessment of Composite Cases
- Service Life Methodology Verification
- Motor Environment Evaluation
- Tri-Service Standard Test Methods
- Low Cost Process Evaluation Motor

TR702

Figure 28.

Ballistic Missile Propulsion....



OBJECTIVES

- To Improve:
  - R & M
  - Component/Motor Performance
  - Manufacturing Cost/Process
- To Develop Technology for New Ballistic Missile Missions
  - High G
  - Relocatable Targets
  - Lethal Defense Penetration

CLUSTERS

- Ballistic Missile Service Life
- Booster and Front-End Technology
- Nozzle & Exit Cone Technology

PAYOFFS

- Increase Range and/or Throw-Weight
- Increase Service Life
- Increase Reliability of Missile Components
- Improve Missile Component Processing Techniques

TR657

Figure 29.

e. Future Work

The broad scope of future work for the three principal clusters, Low Signature, Improved Peformance Motors, and Component Assurance are shown in Figures 26, 27, and 28. These are not specific programs but general areas of investigation that will be investigated during the FY 88-92 time period.

4. Ballistic Missile Propulsion Technology

The Ballistic Missile Propulsion Technology thrust contains three clusters to develop technology for future USAF ballistic missile booster systems, upper stages and payload delivery systems. This thrust provides technology for improved performance in range/payload capability, increased reliability, reduced development risk and increased accuracy. This thrust is illustrated and summarized in Figures 29 through 33.

a. Objectives

The overall objectives include developing technologies that will increase booster reliability, enhance service life capability, reduce operation and maintenance costs, increase payload and range capability with reduced size missiles and enable new missions. These objectives will be met by investigating critical areas of solid propellant motor failure modes such as bonded interfaces, chemical migration and propellant aging. Components are being developed that will reduce the weight and volume of future ballistic missiles and that will enable high acceleration ICBM flight. Penetration-aids/re-entry vehicle propulsion will also be developed. New and innovative nozzle designs, simple and economic processing techniques, and characterization of nozzle performance and materials will increase reliability and reduce costs for future nozzles and exit cones. The work in this thrust is performed under four clusters as shown in Figure 29.

b. Clusters

The clusters shown in the lower left quadrant of Figure 29 will be discussed.

(1) Service Life

The Ballistic Missile Service Life cluster is responsible for developing technologies that will increase booster reliability, enhance service life capability, and reduce operation and maintenance costs. This is accomplished by investigating, identifying, and providing technology for controlling the processes which may lead to a high probability of failure in critical areas in a solid rocket motor. Bonded interfaces are being investigated to acquire technology to direct the development and evaluation of structurally superior bonded interfaces. Many unidentifiable chemical interactions (poisonings) take place during motor manufacture. Many more of these "poisonings" have occurred in composite case motors than in metal case motors. A clearer understanding of the propellant/liner/insulation/case chemical activity is needed to predict reliable and age-stable rocket motor interface bonds. Manufacturing and processing variables of high energy propellants will be investigated in order to identify and develop procedures that will ensure the production of reproducible propellants, liners, insulations and bond systems. To understand the interaction between the ballistics and the structural characteristics of a solid rocket motor, work is being done to understand how structural defects are initiated, how to identify these defects using computer tomography non-

Fundamental Technologies

Structural Integrity....

PEACEKEEPER STAGE I WITH CORE ASSEMBLY

OBJECTIVES/GOALS

- Reliably Predict Motor Structural Integrity and Service Life
- Understand and Improve Bonded Interface Technology
- Model Propellant Behavior and Develop Failure Criteria
- Develop Reliable Nondestructive Evaluation Technology

TECHNOLOGY/CHALLENGES

- "Realities" Still Exceed Analysis and Prediction Capabilities
- Bondline is Most Complex Part of Motor
- Quantitative NDE Requires Realistic Failure Criteria
- Propulsion System Hazards Mechanisms Poorly Understood

PAYOFFS/MILITARY SIGNIFICANCE

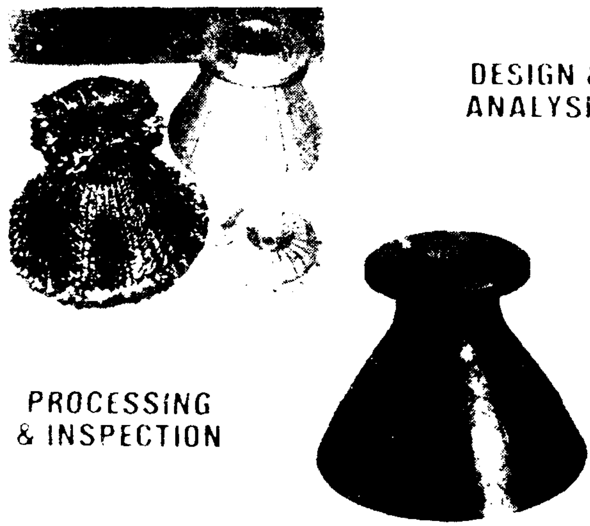
- Increased System Reliability "Build it Right the First Time"
- Increased Confidence in Rocket Launches
- Problem Solving Support to SPO's and AFLC

TR564

Figure 30.

Ballistic Missiles

Nozzle and Exit Cone Technology....



OBJECTIVES/GOALS

- Reliable-100% Inspection on C-C Exit Cones & Nozzles
- Establish 100% Proprietary Free Processing for Nozzle Components
- Provide Analytical Assessments for Prototype Nozzles
- Replace Degrading Insulators

TECHNOLOGY/CHALLENGES

- Quantify Inspections-Develop Accept/Reject Criteria
- Simple and Reliable C-C Processing
- Establish Failure Criteria for Fine Weave 3-D C-C
- Find Viable Non-Degrading Insulators

PAYOFFS/MILITARY SIGNIFICANCE

- Reduced Ballistic Motor Development Time with Lower Risk Nozzles
- Lower Cost Processing, Fewer Rejections
- Higher Reliability at Equivalent Wt
- Eliminate Pressure Ejection Failure in Nozzles Due to Insulator Degradation

TP674

Figure 31.

destructive evaluation technology, and understanding the effects of these defects. This cluster is summarized along with other fundamental structural integrity topics in Figure 30.

(2) Advanced Booster and Front End Technology

The Advanced Booster Technology cluster develops solid rocket motor components that provide growth capability for future ballistic missiles in terms of throw-weight, range, increased basing flexibility, increased survivability, increased reliability and maintainability, and lower life cycle cost. A major technical issue in this cluster is the performance of motor cases. We have discovered new fiber/resin combinations that increase the case efficiency by up to 38 percent. Work is continuing in motor case technology to further improve case efficiency, reliability, processing, and damage assessment. Feasibility was demonstrated of critical Integrated Stage Concept (ISC) technologies. This concept was then transitioned to an advanced technology development program which is being conducted through FY 91. Studies and analyses indicate that applying the ISC to the SICBM can lower booster production costs 40 percent and increase throw-weight 18 percent or range 17 percent. Critical technologies for the high acceleration booster concept were identified. Propellant development for this type booster will be accomplished first, followed by the start of a motor component development program in the out years. Front-end propulsion technologies are also included in this cluster. Two programs have been completed that explored both liquid and solid technologies to reduce the weight of the post-boost propulsion system. Solid staged combustion (SSC) and gas driven intensifier technologies for advanced post-boost propulsion systems were demonstrated. The SSC concept can reduce system weight by 32 percent less than present solid gas generators.

(3) Nozzle and Exit Cone Technology

The Nozzle and Exit Cone Technology cluster summarized in Figure 31 develops nozzle components for future ballistic missiles and space motors. The overall objective of this cluster is to increase the reliability of nozzles and exit cones. Work is being performed in the areas of nozzle materials, design and analysis, nozzle construction, processing science, and nozzle characterization and inspection. In-house studies are underway to develop a "proprietary free" carbon-carbon manufacturing process: to understand the carbon fiber structure, surface properties, oxidation rates, and surface morphology and porosity, and to develop a state-of-the-art thermal-structural analysis capability. We are actively participating in the development of an Advanced Rocket Nozzle Inspection System (ARNIS). The result of this program will be to employ the computer tomography (CT) inspection technique at a nozzle production contractor site. Two systems are to be made operational; one at Kaiser Aerotech and the second at Hercules/Bacchus. A large effort, both in-house and contract, is on-going to understand the significance of the flaws detected by computer tomography machines. A major effort to explore advanced image analysis for advanced CT inspection will be conducted. In the area of nozzle fabrication, a new nozzle fabrication process was evaluated for use in the Small ICBM. The 3D French Novoltex advanced construction exit cone was selected for SICBM Stages II and III. Numerous disciplines are required to explore the art of nozzle and exit cone technology. This cluster helps much of the art become a science.

c. Payoffs

The Ballistic Missile Propulsion Technology thrust provides propulsion technology that enables the Air Force to maintain existing missile systems and to develop new missile systems to satisfy new mission requirements. Technical accomplishments in this thrust have given the Air Force the capability to predict the performance of the missile systems, minimize operational failures, and improve the performance of existing systems. The Advanced Strategic Missile Systems Office depends on the technical accomplishments of the Ballistic Missile Propulsion Technology thrust and assists AFAL in transitioning these technologies into systems.

d. Funding

Table 4 shows the total funds to be expended in the Ballistic Missile Propulsion Technology thrust from FY 87 through FY 89. The following is an identification of the Program Elements supplying funds to this thrust:

11213F - Minuteman Squadrons
61101F - Laboratory Director's Independent Research Funds
61102F - AFOSR Research
62302F - Rocket Propulsion Exploratory Development
63302F - Space and Missile Rocket Propulsion Advanced Technology Development
63311F - Advanced Strategic Missile Systems
64312F - Peacekeeper (MX)
64609F - Reliability and Maintainability Technology Insertion Program
65502F - Small Business Innovative Research
65111F - (FWE)

TABLE 4. Ballistic Missile Propulsion Funding

PROGRAM ELEMENT	FY 88	($K) FY 89	FY 90
11213F	22	22	22
61101F	150	-	-
61102F	462	359	400
62302F	1,378	1,600	1,600
63302F	2,200	2,400	2,200
63311F	1,500	500	-
64312F	200	100	100
64609F	1,318	265	-
65502F	1,548	1,200	-
65111F (FWE)	250	465	195

e. Future Plans

Future work in the Ballistic Missile Propulsion Technology thrust will involve continued efforts to improve the performance and reliability of propulsion systems.

In the Service Life cluster, future work will concentrate on the understanding of propellant aging characteristics and on the development of nondestructive inspection techniques. Two specific efforts involved are studying high energy propellant/case interfacial bondlines and developing accept/reject criteria for the inspection techniques developed. This cluster is summarized in Figure 30.

In the Advanced Booster and Front End Technology cluster, future work is planned for improving component material technologies which include ceramic composite polar bosses, high temperature cases and fixed nozzle TVC concepts. Technologies for penetration aids, re-entry vehicle propulsion and high acceleration will be developed. Integrated Stage Concept technologies will continue to be pursued.

In the Nozzle and Exit Cone Technology cluster future work is planned for fully developing processing and failure criteria for current and advanced construction carbon-carbon materials, implementing computer tomography inspection techniques including the development of accept/reject criteria.

The AFAL Component Laboratory continues to grow and helps us to improve our in-house capabilities in the areas of carbon-carbon and case fabrication. Major goals of the Component Laboratory are to develop nonproprietary processing techniques, characterize advanced fibers and resins, develop material inspection techniques, and establish nozzle and case failure criteria. The program is summarized in Figure 32.

5. Fundamental Technologies

This technical thrust is the germination bed of fundamental design and evaluation techniques directed toward decreased development risks and life cycle costs, increased design reliability of space systems, minimized impact on the environment of rocket propellants and ingredients, and evaluation of the feasibility of advanced concepts for energy conversion. This thrust is illustrated and summarized in Figure 33.

a. Objectives

The Fundamental Technologies major thrust contains five clusters to provide enabling technology to the laboratory major thrusts for rocket propulsion and space vehicle advancement. The five clusters are Spacecraft Sciences, Improved Propellants, Combustion Technology, Structural Integrity, and Applied Research in Energy Storage. This thrust provides the core technologies that serve as the building blocks for propulsion and space vehicle advancements. The thrust provides feasibility demonstration of energy storage concepts, new ingredients, low cost processing methodology, improved safety concepts, structural integrity methodology, means to improve performance, and means to prevent combustion related problems in Air Force missile and spacecraft systems. Basic research programs feed the exploratory development in most areas such as energy storage, combustion, fracture mechanics, chemical synthesis and composite materials.

Advances in this thrust may be incremental, providing a broad base of research and applied technology that contributes to the solution of existing problems, or providing step function improvements and even technology breakthroughs. This thrust uses knowledge from the fundamental physical sciences to generate engineeering problem solving tools. The application of two or more small technology advances can result in a large improvement in system capability. The energy storage cluster is evaluating the

Ballistic Missiles

Nozzle and Exit Cone Technology....

TECHNOLOGY PROGRAM PLAN
FY88-93

- Nozzle Composite Modeling and Failure Criteria on Current and Advanced Composites
  - 2-D Involute & Fine Weave 3-D C-C
  - Non-Degrading Insulators
- Validation Testing of New Concepts, Processing, and Models
  - I-H Exit Cone Validation
  - New Insulators
- Proprietary-Free Methods for Basic & Advanced Nozzle Structures
- Expert System Control of C-C Nozzle Fab
  - Repeatable Techniques, Reduced Cost Potential
- Advanced Computed Tomography & Ultrasonic Inspection Application to Nozzles
  - Defect Imaging and Analysis for Evaluation Criteria
  - Defect Resolution at Sub-pixel Dimensions
  - Far Term Accept/Reject with Expert Systems

TR676

Figure 32.

feasibility of radically new concepts which show potential for dramatic improvements in propulsion capability. Emphasis is on applied research concepts highlighted in AFSC Forecast II deliberations. Innovative means to store energy in atoms and molecules and fundamental antimatter research are receiving primary attention. Spacecraft sciences is a new cluster directed toward application of fundamental chemistry to problems associated with systems in space. Polymer chemistry and chemical vapor deposition techniques will be emphasized to provide improved coatings, lightweight structures and tankage on spacecraft. Improved propellants will emphasize low cost ingredients reproducibility and processing techniques to reduce the cost of propulsion while maintaining or increasing performance capability. Thermoplastic elastomers, TPE, show promise for low cost propellant applications. Life cycle costs can be reduced by carefully developing new components to eliminate costly processing steps and identifying the life limiting design weakest link. Bonded interface improvements and hazards mitigation will be stressed. The combustion cluster will emphasize performance and liquid rocket instability technology. All clusters emphasize working with peers in other organizations to eliminate duplication and build upon technology advances. Transition of know how from this thrust to Air Force systems is the ultimate payoff.

b. Clusters

The clusters shown in Figure 33 will be discussed with the exception of Spacecraft Sciences. This new cluster is currently focused on in-house research projects hopefully leading to contracted efforts in later years.

(1) Improved Propellants

This cluster is summarized in Figure 34. As the name implies, the purpose of this cluster is to develop the technology base for improving the properties of propellants.

As a result of the need for low-cost access to space, major new emphasis is being placed on low-cost propellant ingredients, such as ammonium nitrate (AN) oxidizer and low-cost/continuous processing techniques. The development and use of AN as a propellant oxidizer in place of the currently used ammonium perchlorate oxidizer could reduce the cost of solid propellants by as much as $0.50 per pound. Work in this area is directed toward increasing energy, improving the combustion efficiency of AN propellants, and investigating novel propellant processing methods including extrusion, solution, and dry blend/melt. Not only do all of these methods have the potential to reduce processing costs but they also enable the use of many energetic and low-cost ingredients not previously usable.

Development of thermoplastic elastomers (TPE) for use as solid propellant binders may be critical to the development of novel low-cost propellants/propellant processing techniques for space transportation. Therefore, new in-house and contractual efforts are being initiated to develop TPE-based propellants. The TPEs are unique binders that do not chemically (irreversibly) cure, but cure by physical association of the polymer chains at ambient temperature. This process is reversible at elevated processing temperatures where the polymer chains dissociate, resulting in binder (propellant) melting. The other distinct advantages over current chemically cured propellants include indefinite pot-life and tailorability, reproducible mechanical and ballistic properties, low cost, and applicability to large-scale continuous propellant

5-4-25-1 D2

Fundamental Technologies....

OBJECTIVE

- Advance State-of-the-Art in Core Technologies Applicable to Rockets and Space Vehicles

CLUSTERS

- Spacecraft Sciences
- Improved Propellants
- Combustion Technology
- Structural Integrity
- Applied Research in Energy Storage

PAYOFFS

- Low Life Cycle Costs
- High Performance
- Reliable and Maintainable
- Revolutionary System Capability

TR627

Figure 33.

production. Initial feasibility studies have demonstrated that acceptable propellant mechanical properties can be achieved using low-cost, commercially available TPEs. Small scale rocket motors containing TPE based propellants have been fired.

Efforts are continuing with glycidyl azide polymer (GAP), which is a low hazards energetic binder that offers unique improvements to propellant performance and ballistic characteristics. This unique combination of low hazards and improved performance makes GAP the most likely binder candidate for Class 1.3 minimum smoke and high burn rate propellant applications. In-house programs have demonstrated that "clean" burning GAP/AN/Al propellants can provide comparable theoretical performance to current AP propellants. Current and future programs will finalize GAP modifications and characterization techniques that will lead to the operational use of GAP in the near future.

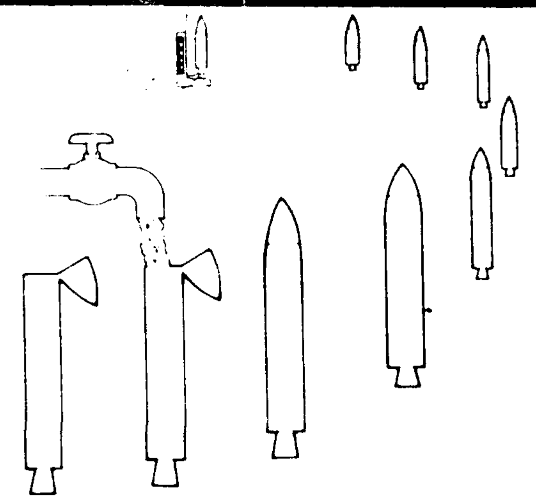
(2) Combustion

This cluster is summarized in Figure 35. The long term goal of this cluster is to improve motor/engine performance and to reduce development risks by developing predictive tools and guidelines which will allow the user to maximize performance and stability, and to minimize internal flow problems during the propulsion system design. For the past 10-15 years, the emphasis has been on developing new solid rocket motors. The long term goal of this cluster is to improve motor/engine performance and to reduce development risks by developing predictive tools and guidelines which will allow the user to maximize performance and stability and to minimize internal flow problems during the propulsion system design. For the past 10-15 years, the emphasis has been on developing new solid rocket motors. Over the next few years this emphasis is being reversed to support the development of new liquid systems for use in space. In addition, we are responding to the need to apply our propulsion based technology to new problems associated with future operations in space.

The coupling of the liquid or solid propellant combustion processes with the acoustic characteristics of the combustion chamber is treated in the Combustion Stability subcluster. In the liquid stability area, several programs are addressing the damping of acoustic energy in liquid rocket combustion chambers. These programs end in FY 90. Another program is attempting to control the damping process using adaptive feedback techniques to vary the characteristics of the damping device to match and cancel the disturbance. In FY 89 we are starting a program to characterize the source of the acoustic disturbance that creates the instability and relate it to the performance of the injector. Our goal is to design the most efficient stable liquid rocket motor possible. Several programs, ending in FY 90, will better define how the propellant combustion process interacts with the acoustic energy generated within a solid rocket motor. These programs will lead to better understanding and avoidance of these solid rocket motor instabilities. Included in this effort is the AFAL portion of a TTCP effort to evaluate the existing methodology for experimentally determining the combustion response of solid propellant to acoustic pressure fluctuations. This new technology will help us avoid costly nonlinear instability problems. No further work is planned in the solid stability area until after FY 93.

Fundamental Technologies

Improved Propellants....



OBJECTIVES/GOALS

- Develop Low-Cost Ingredients/ Processing
- Demonstrate Reliability and Performance of Energetic and Low Cost Ingredients
- Advanced Propellants for Future Applications: (Fast Launch, Low Observable, Environmentally Acceptable)

TECHNOLOGY/CHALLENGES

- Thermoplastic Elastomer Propellant Development and Processing
- Efficient Low-Cost Ingredients
- Demonstrate Novel Processess
- Handling Hazardous Ingredients/ Propellants
- Improved Gap Aging and Characterization

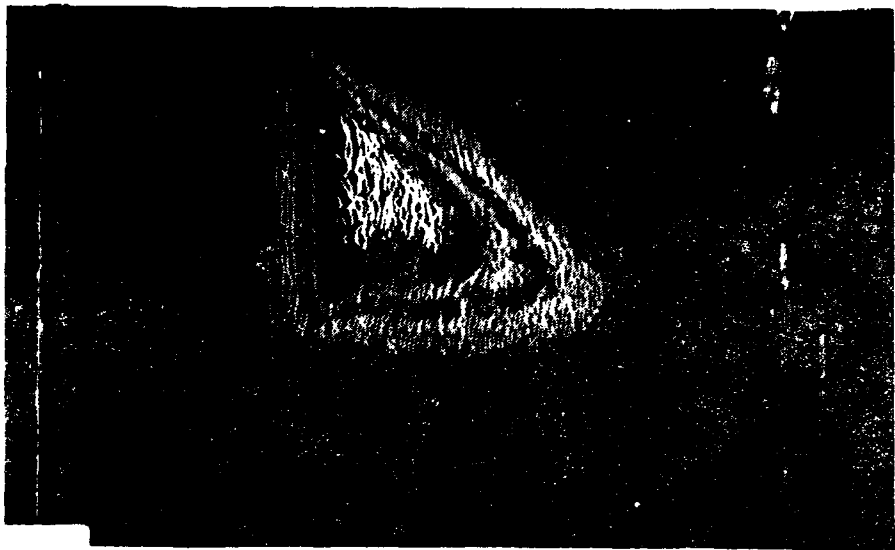
PAYOFFS/MILITARY SIGNIFICANCE

- Low-Cost Space Transportation
- Safe, Energetic, High Performance Propellants
- Extended Service Life and Space Storability

TR631

Figure 34.

Fundamental Technologies
Combustion....



TECHNOLOGY/CHALLENGES
- Predict Internal & External Flows (CFD) and Their Effect on the Vehicle
- Determine Mechanisms of Instability Growth
- Measure Combustion Properties Accurately
- Determine Chemistry of High Temperature, Pressure Combustion

OBJECTIVES/GOALS
- Low-Cost, Reliable, Predictive Liquid Rocket Stability Tools
- Eliminate Flight Induced Head End Erosion
- Extirpate OTV Nutation
- Develop Low Cost, Non-Toxic Propulsion
- Accurately Predict Performance of New Space Engines

PAYOFF/MILITARY SIGNIFICANCE
- Increased Reliability
- Increased Range/Payload
- Reduced Life Cycle Cost
- Reduced Development Time & Risk

TR648

Figure 35.

The Propulsion Performance subcluster treats both combustion chamber and nozzle performance. A program ending in FY 89 will develop a new performance model that will accurately predict the performance for the new large area ratio nozzles being designed for space applications. These new liquid engines will operate in a performance regime in which ground simulation is impossible and accurate extrapolation of ground test results to predict performance in space is critical. A program starting in FY 90 will treat unconventional nozzle designs. Our solid performance prediction effort begins a hiatus in FY 90 with the completion of the very successful joint AFAL/BMO program in head end erosion. Future work dealing with advanced motor performance and slag accumulation prediction will not resume until after FY 93.

The Solid Propellant Behavior subcluster addresses the problems of steady state combustion. Ongoing programs that end in FY 89 will determine ways to decrease the temperature sensitivity of solid propellants, improve combustion efficiency of the inexpensive and environmentally safe ammonium nitrate propellants, and solve the problem of propulsion system induced nutation of spin stabilized satellites. In FY 92 we will begin a program that addresses the problems of high pressure combustion associated with the proposed high acceleration weapons.

(3) Structural Integrity

This cluster is summarized in Figure 35. This cluster develops technology required to assure the structural integrity and service life of solid rocket motors and space related structures. Five subclusters address specific areas within this broad charter. The Structural Analysis subcluster has produced advances in linear finite element analysis codes for solid rocket motors, and efforts continue to develop a generally applicable constitutive theory, notably in the area of microstructural theory. The major emphasis in this subcluster, however, is now on non-linear analysis technology. The major remaining problem is material non-linearity, and an intensive attack on this problem continues. An additional goal in this subcluster is the strengthening and maintenance of AFAL's capability to perform in-house structural analysis of large space boosters and other large solid rocket motors (SRM). The Consolidated Analysis Code program (planned for FY 90) will give AFAL state-of-the-art analysis capability in the area of large solid rocket boosters.

The primary ongoing effort in the Failure Analysis subcluster is research on propellant fracture, with emphasis on the effects of strain fields and property gradients. This research will feed into work being done to develop structural analysis codes based on propellant microstructure and an effort to develop a unified propellant failure theory (starting in FY 91). Research on the failure characteristics of thermoplastic elastomers will also be conducted under this subcluster.

The efforts in the Structural Evaluation subcluster are aimed at resolving problems in propellant surface strain measurement. This technology is needed to evaluate analysis techniques as well as to directly evaluate motor structural integrity. The effects of the space environment on SRM components will be evaluated under this subcluster also.

The hazards subcluster provides the experimental efforts which maintain the AFAL's in-house capability to evaluate propellant hazards. Current in-house and contracted efforts include characterizing the sensitivity of propellants to electrostatic discharge (ESD).

The Bonded Interface Technology subcluster is the most heavily emphasized in the cluster. The goals are to understand and control the structural integrity and service life problems related to the motor interfaces: propellant/liner, liner/insulator, and insulator/case. One of the efforts is aimed at developing a computer code which will predict the migration and chemical reaction of mobile ingredients within a rocket motor, and to determine the resulting material properties for input to structural and service life analysis. Another effort will demonstrate the effectiveness of "insuliners" in solid rocket motors. The insuliner replaces the insulation and liner with a single material. This reduces the number of interfaces and greatly increases the reliability of the propellant grain through decreased complexity and fewer migrating ingredients. The AFAL is also establishing an in-house capability in this area.

(4) Applied Research in Energy Storage

High Energy Density Matter Technology Area

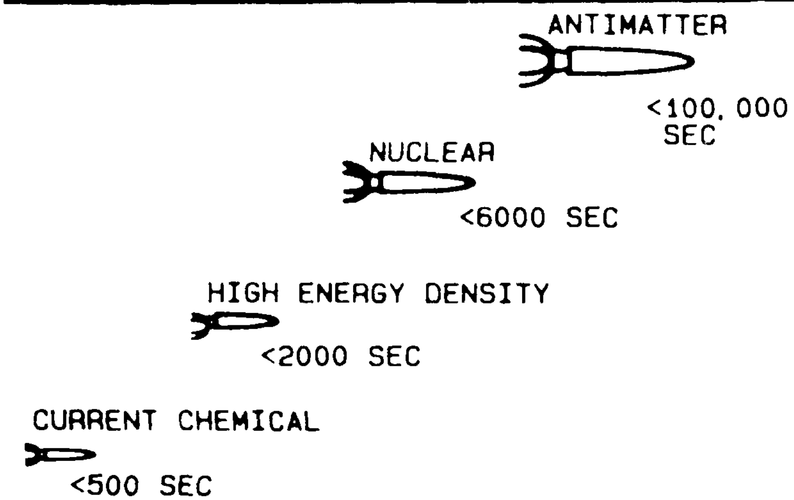
This cluster is summarized in Figure 36. The long term thrust of the High Energy Density Matter technology area is to create, stabilize, characterize and develop high energy density matter for potential use as propellants, fuels, and explosives. During the 1960's, there was much interest in exploiting such high energy species as metastables and free radicals. Unfortunately, the necessary computational and diagnostic capabilities were not available and most of the work ceased. With the advent of super computers, much more accurate computer solutions are being done. With the tremendous advances in laser technology, not only are extremely fast selective, and sensitive diagnostics available but also the knowledge of metastables in laser plasmas gives insight that was previously lacking. These advances, along with new chemical bonding theories, have generated a renewed interest in the area of high energy density matter.

Current emphasis in this area is on theoretical and experimental studies to identify candidate materials possessing very high energy densities to identify decay mechanisms and to determine possible stabilization techniques. The long term thrust of this technology area is to create, stabilize, characterize and develop high energy density matter for potential use as propellants, fuels, and explosives. During the 1960's, there was much interest in exploiting such high energy species as metastables and free radicals. Unfortunately, the necessary computational and diagnostic capabilities were not available and most of the work ceased. With the advent of supercomputers, much more accurate computer solutions are being done. With the tremendous advances in laser technology, not only are extremely fast selective, and sensitive diagnostics available but also the knowledge of metastables in laser plasmas gives insight that was previously lacking. The availability of these new tools, along with new chemical bonding theories, have generated a renewed interest in the area of high energy density matter.

6-4-25-1 D54

Fundamental Technologies

Applied Research in Energy Storage....



OBJECTIVES/GOALS

- Exceed Current Chemical Limitations
- Identify, Create, Stabilize and Characterize Candidate Substances
- Establish National Antimatter Consortium
  - AF, DOE, NSF, NIH,...
- Demonstrate Antimatter Enabling Technologies

TECHNOLOGY/CHALLENGES

- Accurate Theoretical Predictions
- Stability and Energy Density
- Cost-Effective Production Collection, and Storage of Antimatter
- Application Designs

PAYOFFS/MILITARY SIGNIFICANCE

- Increase Payload per Mission
- Allow Single Stage to Orbit
- Enable New Missions
- Provide Spin-Off Benefits
  - Lasers/Explosives
  - Materials Science
  - Medical Science

TR641

Figure 36.

Current emphasis in this area is on theoretical and experimental studies to identify candidate materials possessing very high energy densities and will identify decay mechanisms and possible stabilization techniques. New candidates include asymmetric N_2O_2, a potential high energy oxidizer. Progress has also been made toward stabilizing high energy azides and high energy forms of frozen hydrogen. Stabilization efforts parallel the creation efforts. Feedback among identification, creation and stabilization efforts is enhanced by annual conferences held jointly with AFOSR. As stable products become available, they will move into characterization efforts to determine physical and chemical properties. Since there is a high likelihood of some of the end products being different than current propulsion systems, conceptual engineering studies will be needed to determine how to best use the available energy.

Antimatter Technology Area

Antimatter represents the highest possible energy storage density known to science. Microscopic amounts of antimatter could in principle be used to heat propellants to arbitrarily high exhaust velocities, enabling rockets for existing missions to be much smaller, and enabling new high velocity missions. Currently, antimatter must be made in high energy "atom smashers" at very great expense and at rates too small for practical use, however approaches to higher efficiency exist. It yields its energy whenever it is allowed to come in contact with normal matter, and thus must be produced and stored in isolation from normal matter until needed.

AFAL and RAND Corporation organized an assessment of antimatter technology, needed to determine if antimatter can eventually be produced, stored and used in the quantities needed for propulsion at a reasonable price. The AFAL/RAND assessment included input from national experts in all of the technologies required to take antimatter from production to application. It concluded that there are substantial near-term scientific, engineering and medical benefits to having a U.S. source of low energy antiprotons and that scaled-up production might be possible from this technology base. The AFAL is working to encourage the creation of such a source at an existing national accelerator and is investigating the theory of efficient antiproton production with Brookhaven National Laboratory. The most promising way to store antiprotons in high densities would be to combine them with anti-electrons (positrons) to make antihydrogen, form antihydrogen cluster ions, and then grow the cluster ions into charged crystals of antihydrogen ice. AFAL has initiated a project to investigate technology for growing hydrogen cluster ions without contact with normal matter. These methods would then be used for antihydrogen.

c. Payoffs

Figures 32-36 show some of the payoffs that can be realized through development of these fundamental technologies. New, better, and cheaper ways to provide more reliable space and rocket systems best describes the payoff of this thrust. The programs in this thrust provide the basic ground work from which our understanding of space and rocket propulsion technology evolves; these are our "core technologies." The understanding derived from this thrust allows us to investigate innovative higher energy density concepts, to develop improved propellants for increased rocket performance, and to provide low risk, low cost concepts and approaches. Efforts are under way that promise to reduce propellant processing costs. Improved knowledge of bonded interface phenomena will result in higher performance and greater reliability for Air Force missiles.

Fundamental Technologies

Transition Targets....

- Applications Thrust
  - Low Cost, Energetic, Safe Propellants
  - Stable Combustion, High Efficiency
  - Improved Design Tools (Liquids and Solids)
- Logistics R&D
  - Before the Fact Improvements
  - After the Fact Solutions
- Forecast II
  - High Energy Density Propellant (PT-1)
  - Antimatter Propulsion (PT-42)
  - Active/Passive Broad Spectrum Signature Control (PT-18)
  - Long Range Air-to-Air Missiles (PS-12)
  - Advanced Heavy Lift Space Vehicle (PS-24)
  - Space-based Reusable Orbit Transfer Vehicle (PS-28)

T5629

Figure 37.

Figure 37 identifies the Fundamental Technologies thrust transition targets. Transition to the applications thrusts is the significant output of technology from this thrust. We seek energetic, chemically stable and safe propellants. The combustion process must be stable and efficient. Improved design tools are needed for structural and combustion analyses. Advanced concepts for potential high energy density materials and antimatter research are needed to meet the requirements of AFSC Project FORECAST II. The concepts are high risk, but have very high payoff potential. In a generic sense, all improvements must be made without compromising logistics requirements. We seek before the fact improvements and after the fact solutions.

d. Funding

Table 5 shows the funding we plan to apply to this thrust. The Program Element 61101F monies are from the Laboratory Director's Independent Research Fund. The 61102F monies are AFOSR research funds being applied to rocket propulsion goals, Project 5730. The 62601F monies are Advanced Weapons resources being applied to energy storage goals. The exploratory development investigations are accomplished under Program Element 62302F, Project 5730. The 64312F funds ae for ICBM modernization. The 64609F funds are part of the Reliability and Maintainability Technology Insertion Program. The 65502 funds are from the Small Business Innovative Research program. The 65807 funds are Test and Evaluation monies from AEDC. The 78011F funds are Industrial Preparedness monies for improved manufacturing technology (MANTECH) from AFWAL.

TABLE 5. Fundamental Technologies

($K)

PROGRAM ELEMENT	FY 88	FY 89	FY 90
61101F	319	100	-
61102F	2,015	1,917	1,751
62601F	290	60	-
62302F	6,666	6,542	6,800
64312F	530	-	-
64609F	200	600	500
65502F	800	1,200	950
65307F	250	250	100
78011F	-	700	1,000

e. Future Plans

Figures 38-41 identify the project emphasis in this thrust. They are presented in the general order according to the cluster responsible for the work.

ORGANIZATION

AFAL organizational chart as of July 1988 is shown in Figure 42.

FACILITIES

AFAL facilities are shown pictorially in Figure 43.

Fundamental Technologies

Improved Propellants....

TECHNOLOGY PROGRAM PLAN
FY88-93

- Reproducibility of GAP Through Stabilization
- Safe High Performance Ingredients Through Encapsulation
- Advanced Processing Through On-Line Characterization
- Large Scale Low Cost Processing
- Thermoplastic Elastomer Motor Evaluation
- Far Term Technology Development Such as Extinguishable Solid Propellants and Liquid Injected Solid Motors

TR633

Figure 38.

A1238-D28

Fundamental Technologies

Combustion....

TECHNOLOGY PROGRAM PLAN FY88-93

- Combustion Stability Technology
- Propulsion Performance Technology
- Solid Propellant Behavior Technology
- Astronautics Technology

TR652

Figure 39.

Fundamental Technologies

Structural Integrity....

TECHNOLOGY PROGRAM PLAN FY88-93

- Quantify and Control Propulsion System Material Properties that Cause/Enhance Hazards
- Develop New Instrumentation and Methodologies for Improved Structural Evaluation Capability
- Develop Advanced Nonlinear Structural Analysis Codes and Improve/Consolidate Existing Codes
- Identify Causes/Effects of Failure in Solid Rocket Propellant
- Improve Capability to Nondestructively Evaluate Solid Rocket Motors
- Understand and Model Chemical and Physical Mechanisms that Affect Bonded Interfaces - Improve Interface Properties

Figure 40.

A1238-018

Fundamental Technologies

Applied Research in Energy Storage....

TECHNOLOGY PROGRAM PLAN FY88-93

- High Density Matter
  - New Bonding Theories
  - Theory Screening
  - Experimental Verification
  - Stabilization
  - Conceptual Engineering

- Antimatter
  - Studies and Analysis
  - Dense Storage Technology

TR645

Figure 41.

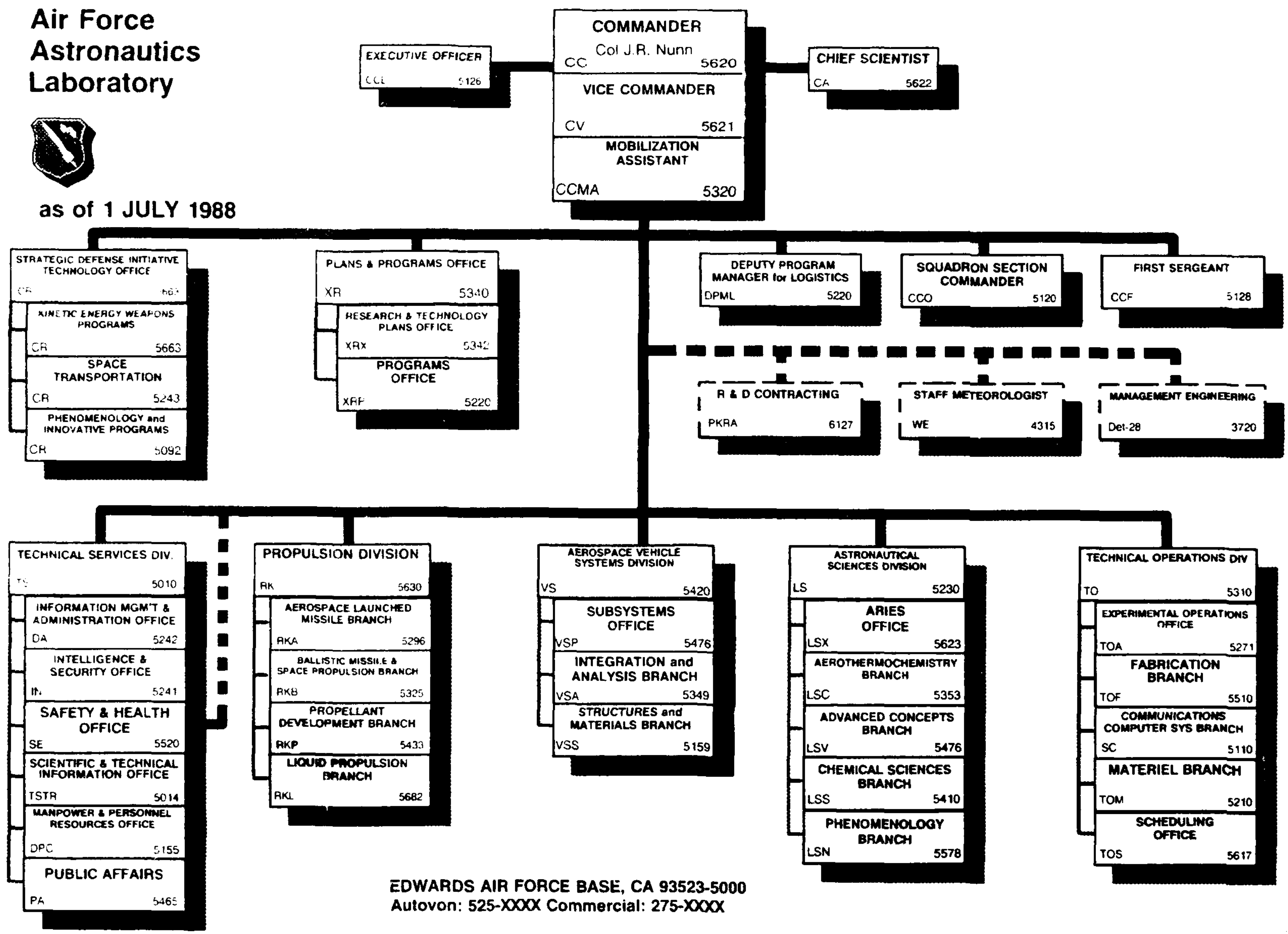

Air Force
Astronautics
Laboratory
as of 1 JULY 1988
EXECUTIVE OFFICER
5126
COMMANDER
Col J.R. Nunn
CC 5620
VICE COMMANDER
CV 5621
MOBILIZATION ASSISTANT
CCMA 5320
CHIEF SCIENTIST
CA 5622
STRATEGIC DEFENSE INITIATIVE TECHNOLOGY OFFICE
KINETIC ENERGY WEAPONS PROGRAMS
CR 5663
SPACE TRANSPORTATION
CR 5243
PHENOMENOLOGY and INNOVATIVE PROGRAMS
CR 5092
PLANS & PROGRAMS OFFICE
XR 5340
RESEARCH & TECHNOLOGY PLANS OFFICE
XRX 5342
PROGRAMS OFFICE
XRP 5220
DEPUTY PROGRAM MANAGER for LOGISTICS
DPML 5220
SQUADRON SECTION COMMANDER
CCO 5120
FIRST SERGEANT
CCF 5128
R & D CONTRACTING
PKRA 6127
STAFF METEOROLOGIST
WE 4315
MANAGEMENT ENGINEERING
Det-28 3720
TECHNICAL SERVICES DIV.
5010
INFORMATION MGM'T & ADMINISTRATION OFFICE
DA 5242
INTELLIGENCE & SECURITY OFFICE
IN 5241
SAFETY & HEALTH OFFICE
SE 5520
SCIENTIFIC & TECHNICAL INFORMATION OFFICE
TSTR 5014
MANPOWER & PERSONNEL RESOURCES OFFICE
DPC 5155
PUBLIC AFFAIRS
PA 5465
PROPULSION DIVISION
RK 5630
AEROSPACE LAUNCHED MISSILE BRANCH
RKA 5296
BALLISTIC MISSILE & SPACE PROPULSION BRANCH
RKB 5325
PROPELLANT DEVELOPMENT BRANCH
RKP 5433
LIQUID PROPULSION BRANCH
RKL 5682
AEROSPACE VEHICLE SYSTEMS DIVISION
VS 5420
SUBSYSTEMS OFFICE
VSP 5476
INTEGRATION and ANALYSIS BRANCH
VSA 5349
STRUCTURES and MATERIALS BRANCH
VSS 5159
ASTRONAUTICAL SCIENCES DIVISION
LS 5230
ARIES OFFICE
LSX 5623
AEROTHERMOCHEMISTRY BRANCH
LSC 5353
ADVANCED CONCEPTS BRANCH
LSV 5476
CHEMICAL SCIENCES BRANCH
LSS 5410
PHENOMENOLOGY BRANCH
LSN 5578
TECHNICAL OPERATIONS DIV
TO 5310
EXPERIMENTAL OPERATIONS OFFICE
TOA 5271
FABRICATION BRANCH
TOF 5510
COMMUNICATIONS COMPUTER SYS BRANCH
SC 5110
MATERIEL BRANCH
TOM 5210
SCHEDULING OFFICE
TOS 5617
EDWARDS AIR FORCE BASE, CA 93523-5000
Autovon: 525-XXXX Commercial: 275-XXXX

Figure 42.

Air Force Astronautics Laboratory
Facilities....

Est. $1B
Replacement Cost

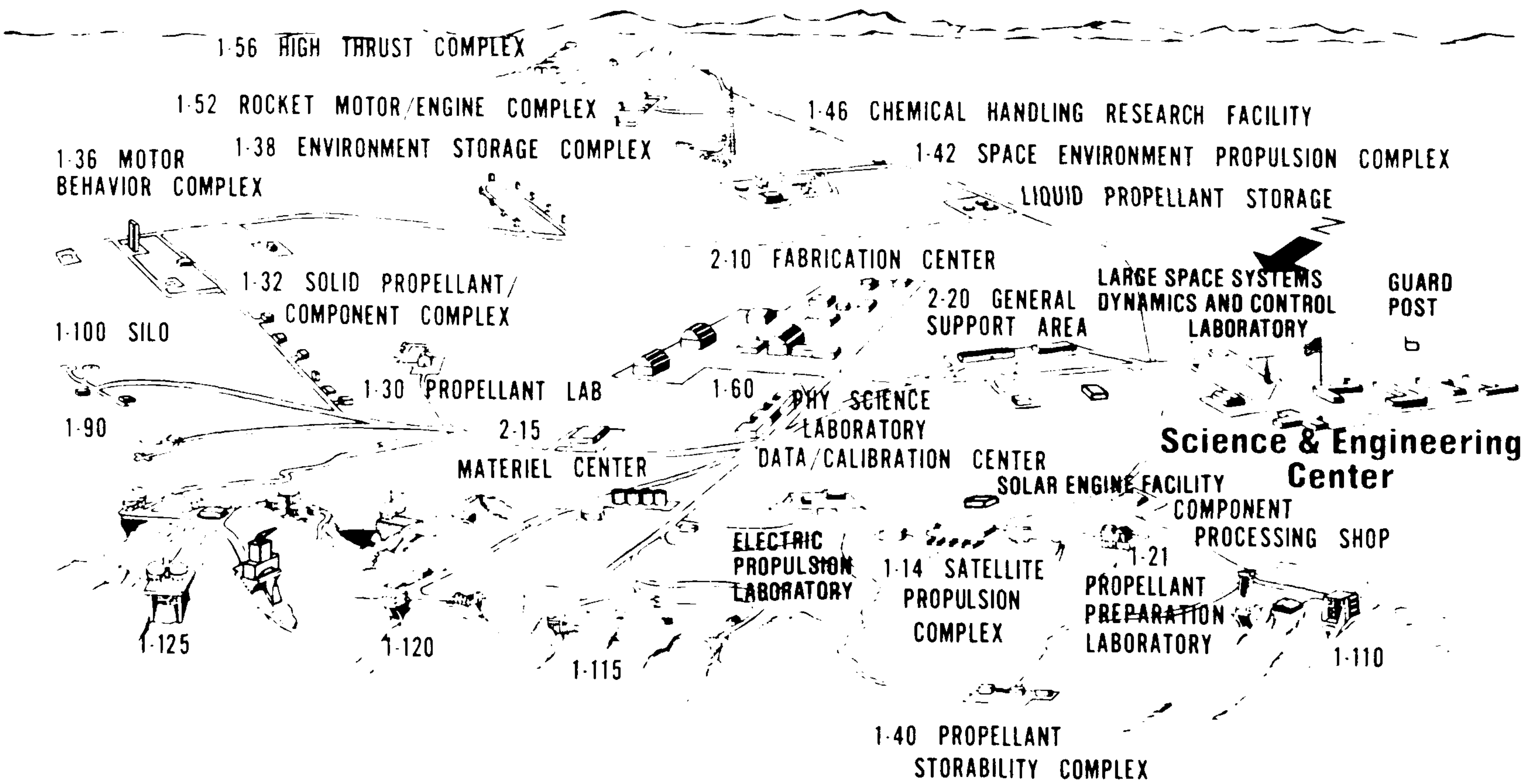


Figure 43.

APPENDIX

FY 89 & 90 COMPETITIVE PROGRAM LISTING

Notes:

1. This list contains those programs we expect to award to industry competitively.

2. The program work units are organized by Technical Thrust.

3. This program list was prepared as a "slice in time" and is subject to changes.

FY 89 SPACE SYSTEMS PROPULSION PLANNED NEW STARTS

TITLE: Vaneless Turbine Eval

PERFORMANCE PERIOD: Aug 89 - Jul 92

OBJECTIVE: Evaluate the aerodynamic performance of vaneless turbines which will allow high temperature operation (up to 2500F) while reducing the penalties associated with turbine cooling. A preliminary design of the vaneless turbine will be accomplished to establish overall configuration and cooling requirements. The design will be refined through optimization studies to estalish the number and shape of the counter-rotating turbine blades, materials, and cooling requirements. Hardware will be fabricated for air rig tests. These tests will verify turbine performance in simulated environments and provide best transfer data to verify cooling capability.

TITLE: CVD Tech Demo

PERFORMANCE PERIOD: Nov 88 - Sep 90

OBJECTIVE: Assess the extent to which iridium chemical vapor deposition (CVD) coatings can provide increased thermal and oxidative resistance. Simulated engine components will be manufactured and coated by a chemical vapor deposition (CVD) process. CVD chamber shape and flow of the deposition gas will be optimized. The simulated components will be of various construction materials and will be coated with Ir, Pt or allows of IR, IQ90. These coated materials will be placed in chemically aggressive environments to simulate engine operation. The value of diffusion limiting interlayers will be assessed. Cu, Ni, and Niobium alloys will be the principal materials of construction.

TITLE: High Thrust Injector Demo

PERFORMANCE PERIOD: Apr 89 - Sep 91

OBJECTIVE: Develop a stable injector configuration at the 10 - 20 K pound thrust level utilizing XLR-132 technology. Scaling that technology to a higher thrust level is most difficult in the area of injector stability. A conceptual engine design will be developed, an injector will be designed in detail and demonstrated. The injector design verification will include significant stability analysis.

TITLE: Integrated ACS Study

PERFORMANCE PERIOD: May 89 - Apr 90

OBJECTIVE: Provide a technology plan for a high performance extended life ACS thruster and feed system components design for integration with a primary storable pump-fed (N204/MMH) orbit transfer and maneuvering system. Input from the Advanced Spacecraft Feed System and the XLR-132 storable engine development programs will be used to initiate studies and analysis to determine the feasibility of integrating the primary, attitude control, orbit transfer, and maneuvering propulsion systems. The analysis will define the most effective means for integrating these systems and identify technology needs. Considerations for reducing cost and improving reliability is also included.

TITLE: 30-KWe Class Arcjet ATD

PERFORMANCE PERIOD: Mar 89 - Aug 92

OBJECTIVE: Develop a prototype 26-kilowatt-electric (KWe) ammonia arcjet propulsion system consisting of a thruster, a power conditioning subsystem, a propellant storage and delivery subsystem, a thermal management subsystem, and a control subsystem, and to demonstrate it in space. This project will have four major phases of technical effort. In the first phase, the contractor will develop the thruster, the power conditioning subsystem, the propellant storage and delivery subsystem, the thermal management subsystem, and the control subsystem. In the project's second phase, the contractor will integrate each of these five subsystems into a single propulsion system and evaluate its performance under simulated space conditions. As part of the project's third phase, the contractor will work with the Air Force to qualify the arcjet system for a space test. In the final phase of the project, the contractor will support the Air Force during the arcjet payload integration and the space demonstration mission.

FY 89 SPACE VEHICLE TECHNOLOGIES PLANNED NEW STARTS

TITLE: Struct Eval of SBR Concepts

PERFORMANCE PERIOD: Mar 89 - May 90

OBJECTIVE: Perform a complete structural performance evaluation of two candidate Space Based Radar (SBR) concepts in the presence of environmental and on-board disturbances. In task 1, structural finite element models of the two SBR concepts selected by the USAF will be developed for radar performance evlauation. The models will be analyzed to determine the natural frequencies and the mode shapes of the system. Task 2 will develop mathematical models for the mechanical disturbances experienced in orbit such as temperature changes, retargeting and station keeping forces, etc. The structural response of the system under both static and dynamic loading conditions will be determined in task 3. If required by the mission, structural vibrations due to mechanical slew maneuvers will also be determined. Task 4 will integrate the structural response with an antenna performance code to determine the distortions in the antenna far field pattern in the presence of structural vibrations. The study will provide an estimate of the amount of structural vibration control required to limit the distortions in the antenna pattern to an acceptable level.

TITLE: TVS Components Demo

PERFORMANCE PERIOD: Jun 89 - May 92

OBJECTIVE: Develop and demonstrate the components of Thermodynamic Vent Systems (TVS) for space storage of cryogenic fluids. A trade study will be performed on the TVS flow and pressure control system design options to identify two or more design approaches which satisfy requirements for long term space storage of cryogenic systems. A simulated TVS system, capable of subjecting the flow and pressure control components to the expected operating conditions will be fabricated. Tests will be conducted to verify that the system provides the required flow and pressure control. Reliability and potential failure modes of the system will be addressed and the critical components subjected to accelerated life testing.

TITLE: LDR System Design Model

PERFORMANCE PERIOD: Mar 88 - Feb 89

OBJECTIVE: To upgrade the Liquid Droplet Radiator (LDR) system design model. The current LDR design code will be evaluated for its adaptablity. Its weight and size prediction algorithms will be assessed for their accuracy and adequacy to analyze a wide range of possible LDR configurations. The current code will be modified or a new code developed based upon the previous model evaluation. The new, more user friendly code will have the capability to design and analyze building block LDR configurations. It will also incorporate optimization algorithms which will allow the LDR system design to be optimized for specified constraints.

FY 89 SPACE VEHICLE TECHNOLOGIES PLANNED NEW STARTS (Continued)

TITLE: Space Heat Exchanger Ground Demo

PERFORMANCE PERIOD: Jan 89 - Jun 91

OBJECTIVE: Demonstrate the operation of a direct contact heat exchanger in a simulated space environment. Analyses will be conducted to establish representative heat exchanger designs for a selected number of potential applications. Detail design, including operating conditions and test parameters, will be generated for the preferred configurations. Test hardware will be fabricated and tested in a simulated space environment to gather performance data. The data will then be correlated with analytical predictions to assess concept feasibility.

TITLE: Adv Spacecraft Technology Integration

PERFORMANCE PERIOD: Mar 89 - Feb 90

OBJECTIVE: Outline the specific details of a program that will provide an effective means of demonstrating advanced spacecraft technologies in the space environment. The general approach to this effort is to identify candidate technologies for demonstration and to investigate means by which the demonstrations could be integrated into a flight experiment. After the technologies are identified, a search will be performed to locate a planned satellite that could be used as host for the demonstration experiments. If a host can be identified, methods for integrating the demonstrations and collecting data will be studied and evaluated. If a host cannot be identified, the feasibility of designing and building a dedicated statellite will be evaluated.

FY 89 AIR-LAUNCHED PROPULSION PLANNED NEW STARTS

TITLE: 1.3 GAP Propellant Bondline Aging

PERFORMANCE PERIOD: Jun 89 - Sep 92

OBJECTIVE: The service life limiting reactions for Class 1.3 GAP propellant and propellant/insulation bondlines are not adequately understood. This lack of understanding precludes the selection of methodologies to improve structural and chemical stability during aging. This project shall elucidate reactions occuring during aging that are detrimental to 1.3 GAP propellant and propellant/insulation bondline structural integrity. Results shall be used to improve the structural and chemical stability of Class 1.3 GAP propellant and propellant/insulation bondlines. Extended service life and reliable predictive methodology of Class 1.3 GAP propellant solid rocket motors shall be the results of this project. The technology can be transitioned to any missile system using Class 1.3 GAP solid propellant rocket motors.

TITLE: Detonation Mitigating Liner/Insul/Case

PERFORMANCE PERIOD: Aug 89 - Jul 91

OBJECTIVE: Currently air-launched solid rocket motors containing high energy, Class 1.1 hazards propellant can be detonated. This detonability requires that these Class 1.1 motors adhere to strict quantity-distance handling and storage regulations. This effort will reduce the shock-to-detonation sensitivity of solid rocket motors. This will enable the Air Force to use hazards Class 1.1, high energy minimum smoke solid rocket propellant. It will also allow the Air Force to have larger numbers of solid rocket motors in current facilities because the motors containing the detonation mitigating liner/insulation/case systems will be less apt to spontaneously or sympathetically detonate. All users of solid rocket motors would benefit from this project, especially the Air Force, as it would enable the Air Force, TAC, to use high energy, minimum smoke propellants; and the Army, as they already have Class 1.1 motors fielded. This project will greatly reduce the hazards associated with handling storage and operation of currently detonable solid rocket motors.

TITLE: Advanced Tactical Missile Signature Study

PERFORMANCE PERIOD: Jan 89 - Sep 90

OBJECTIVE: We are expending significant resources reducing the signature of tactical missile motors. We need to determine if a further reduction of missile signatures is needed or required. Since reducing motor signatures generally reduces motor performance, we need to determine the break even point between the two. We need to look at how this tradeoff effects missile lethality and aircraft survivability.

TITLE: Low Shock Igniter

PERFORMANCE PERIOD: Jan 89 - Jun 90

OBJECTIVE: State-of-the-art rocket motor igniters cause a pressure spike upon ignition. If this spike is significant enough, the propellant grain may be damaged causing catastrophic failure upon motor ignition. This program is intended to develop a foamed pyrotechnic igniter that will deflagrate instead of detonate in order to reduce the pressure spike. At the same time the igniter needs to generate ample heat flux to the inner bore, adequate pressure for motor ignition, reduced smoke from ignition, and adequate transit time for motor ignition. This effort will benefit the Air Force by reducing the risk of propellant damage at ignition thus increasing reliability and will allow the motor case to be designed to a lower operating pressure due to the reduced ignition spike. Users directly benefiting from this technology include TAC, SAC, and all major weapon systems.

TITLE: Low Cost Process Evaluation Motor

PERFORMANCE PERIOD: Sep 89 - May 92

OBJECTIVE: *Many of the new technologies developed in recent years are costly to* fabricate. As part of a rocket motor. To help transition this technology into systems the cost of these technologies need to be reduced. This project will investigate, design, develop, and demonstrate new and innovative processing procedures for producing air-launched solid rocket motors. Processes for reducing the cost of new propellants, composite cases, carbon-carbon nozzles insulators, pulse motor separation techniques, etc. will be investigted. The overall objective is to cut costs while maintaining the high performance levels of the advanced technologies.

FY 89 BALLISTIC MISSILE PROPULSION NEW STARTS

TITLE: Pen-Aid/RV Technology Development

PERFORMANCE PERIOD: Feb 89 - Jan 93

OBJECTIVE: The increasing Soviet Anti-Ballistic Missile (ABM) threat will require the U.S. reentry vehicles to have better penetration capability. Relocatable targets may require mid-course trajectory changes. Powered penetration aids or reentry vehicles could mid-course correct for relocatable targets, simulate or desimulate each other, maneuver to avoid intercept exoatmospherically, or eliminate deployment buses by self-deployment. A key factor against these concepts has been propulsion unit weights. This program would address the weight reductions possible in light of the recent miniaturized units built for kinetic kill vehicle divert propulsion systems.

TITLE: Fast Burn Missile Technology

PERFORMANCE PERIOD: Jan 89 - Dec 89

OBJECTIVE: Efforts in this area directed toward designing, analyzing, and building specific propulsion technologies to be employed in future fast-burn missile boosters. Fast-burn missile technology would enhance survivability to attack by a Soviet layered defense system by providing the capability to (1) escape incoming warheads by rapidly clearing the silo, and (2) defeat the boost-phase intercept system by completing the boost phase while inside the atmosphere. The technology development effort is expected to address propellants, advanced materials, creative component design approaches, and/or innovative manufacturing methodologies. This work will support Air Force ballistic missile missions and will be applicable to SDI exo- and endo-atmospheric interceptors as well as space-based interceptors.

TITLE: Nuclear Propelled ICBM Upper Stage

PERFORMANCE PERIOD: Jun 89 - May 91

OBJECTIVE: The objective of this effort is to develop nuclear propulsion technology for application to future ICBM upper stage propulsion requirements. Present propulsion capabilities limit ICBM throw weight for given total system mass and range restrictions. A nuclear upper stage provides a high mission energy stage to increase the throw weight or reduce total system mass for a given throw weight. This effort focuses on conducting the mission, integration, performance, and safety analysis required to develop technology for this application. It also verifies, at the component level, technology required to demonstrate nuclear propulsion engine operation. The end result of this effort should be the ground work upon which the Ballistic Missile Office could build the next generation ICBM using a nuclear upper stage employing advanced booster technology.

TITLE: Defect Image Analysis

PERFORMANCE PERIOD: Sep 89 - May 93

OBJECTIVE: The eye can not adequately distinguish, position, and evaluate anomalies present within current Non-Destructive Evaluation (NDE) data on nozzles. Advanced computational image analysis would allow anomaly definition and positioning of defects for engineering evaluation and corrective action. The specific goal is to incorporate advanced image processing techniques into representative NDE inspection methods employed on solid rocket nozzle components. Rocket nozzle assemblies contain composite components and bondlines in which 2 mil thick defect imaging and placement is necessary to assess proper function. Advanced imaging of detrimental conditions can minimize agonizing and costly delays and save cost parts. This program will support improved imaging and evaluation of composite based nozzle components for initial part acceptance and then for reappraisals of impacted and aging component assemblies.

FY 89 FUNDAMENTAL TECHNOLOGIES PLANNED NEW START

TITLE: Liquid Stability Mechanisms

PERORMANCE PERIOD: May 89 - May 92

OBJECTIVE: Investigate the basic mechanisms causing combustion instability in liquid rocket engines. Current technology has focused on damping out harmful pressure oscillations, rather than preventing their occurrence, due to a fundamental lack of understanding about how these combustion instabilities arise. Under this effort the basic mechanisms will be investigated with a long range view toward understanding and controlling the processes. A fundamental understanding of the causes of combustion instability should ultimately permit the design of stable, high-performing liquid rocket engines without much of the trial and error which is presently necessary. The approach willl be to: conduct literature review to assess the state-of-the-art in experimental techniques and diagnostics; determine type and extent of data which will be useful in developing models of combustion mechanisms; develop experimental procedures and devices for obtaining the necessary data; potential data may concern characteristics of droplets and spray patterns, droplet and stream breakup, chamber flowfield, and pressure measurements. Experimental devices will be heavily instrumented. Analysis of the data should assist investigators to determine instability mechanisms.

FY 90 SPACE SYSTEMS PROPULSION PLANNED NEW STARTS

TITLE: Dual O/F Ratio Combustor

PERFORMANCE PERIOD: Jul 90 - Jun 94

OBJECTIVE: Demonstrate the durability of thrust chamber materials in a range of oxidizing environments. The engine baseline configuration will be defined on the High Performance Oxygen/Hydrogen Engine Definition Studies to be completed in FY 89. Combustion performance and stability analyses will be conducted to assess injector concepts and provide design criteria. Candidate injector concepts will be evaluated in the in-house Injector Spray Characterization facility. Existing sub-scale injectors will be modified to provide dual O/F capability and tests conducted to demonstrate combustion efficiency and stability at oxidizer rich and conventional mixture ratios. Combustion chamber durability will be demonstrated with materials selected for oxidation resistance.

TITLE: Standard Intelligence Engine/Motor Library

PEERFORMANCE PERIOD: Oct 89 - Sep 94

OBJECTIVE: Develop a standard set of nozzle exit plane conditions of ballistic missiles for plume predictions. A standard set of nozzle/chamber conditions will be obtained from the propulsion and intelligence community and compiled into a standard format. A standard nozzle code will then be used to calculate exit plane conditions. These conditions will be published and will provide consistent startline conditions for intelligence assessment.

TITLE: Advanced Reduced Signature Concepts

PERFORMANCE PERIOD: Oct 89 - Sep 94

OBJECTIVE: Investigate missile and spacecraft system signature reduction methods. Signature reduction would be effected by lowering radiant emissions to neur detection background or shifting the peak radiance to a waveband that is more difficult to detect. Advanced propellants, repackaging, and unique engine designs are methods that could be applied to reduce signatures.

TITLE: Porous Disc Solar Rocket

PERFORMANCE PERIOD: Oct 89 - Sep 91

OBJECTIVE: Demonstrate the performance capability of a porous disc solar thermal thruster concept. A computer model of the flow and heat transfer characteristics of selected porous materials will be developed. Subscale testing will then be performed to verify the analytical work. A full-scale porous disc will be designed and built based on these results. Tests will be conducted to verify the temperature distributions and pressure drops throughout the absorber, determine the energy losses through the walls from the nozzle, and through re-radiation back through the window. Maximum efficiency will be determined through the varying thickness of the discs.

TITLE: Fusion Propulsion Analysis

PERFORMANCE PERIOD: Jun 90 - Sep 91

OBJECTIVE: Technology assessment of fusion for future rocket propulsion systems. An in depth analysis of the fuel cycle and the plasma physics involved in the fusion process in the geometry of interest will be conducted to be followed by an in-depth analysis of the fusion propulsion system, including all of its components and their interactions. Mission analyses and performance of the fusion propulsion concept with comparisons of other advanced propulsion concepts that are planned or likely for similar Air Force missions will be conducted.

FY 90 SPACE VEHICLE TECHNOLOGIES PLANNED NEW STARTS

TITLE: Deployment Verification Experiment

PERFORMANCE PERIOD: Aug 90 - Jul 93

OBJECTIVE: Validate a spacecraft structural model computer program using data from a host satellite during deployment. The general approach of this effort is to use the deployment prediction code to simulate the deployment of actual spacecraft and compare the results to data obtained from the host satellite during deployment. After a host satellite is identified, any deployment processes it employs (solar panels, antennas) will be modeled and simulated using the deployment prediction code. Data required to sufficiently evaluate the code will be determined and the instrumentation necessary to collect it will be identified and integrated with the host satellite. After data retrieval, the performance of the code will be evaluated and modifications to the code will be considered if necessary.

TITLE: System ID for Large Precision Structures

PERFORMANCE PERIOD: Mar 90 - Apr 93

OBJECTIVE: Develop and test an integrated technique for ground-based and on-orbit system identification of future precision space structures. An integrated approach for determining an accurate mathematical model of large precision space structures will be developed. The overall goal of identification will be split between system modeling, ground tests and on-orbit identification tasks, each providing progressively higher accuracy models. Recent results from USAF and NASA sponsored research in optimal sensor location, data compression techniques and optimal input shapes for identification as well as advanced actuation and sensing techniques will be incorporated in the plan. Verification of the approach on a representative space structure will be undertaken. This will include computer simulations and experimental verification tests on the ASTREX facility currently under development at AFAL.

TITLE: Advanced Power Concepts

PERFORMANCE PERIOD: Aug 90 - Sep 94

OBJECTIVE: Identify and demonstrate new and innovative dynamic power cycles optimized specifically for low mass and for reliable operation in the space environment. A comprehensive review of previously completed space powered system studies will establish the range of operating conditions for the dynamic power conversion subsystem. Analyses will then identify candidate thermodynamic power cycles and working fluids that have the potential for high cycle efficiency and reliablity at low specific mass. The specific potential for reaching the power goal, and for having high reliability will be determined. Necessary laboratory and follow-on testing will experimentally verify the analytical results.

FY 90 SPACE VEHICLE TECHNOLOGIES PLANNED NEW STARTS (Continued)

TITLE: Liquid Metal LDR Demo

PERFORMANCE PERIOD: Sep 90 - Feb 93

OBJECTIVE: Develop and demonstrate the technology necessary for operating liquid metal LDR's. Initially suitable liquid metal candidates will be identified through detailed literature searches and supporting laboratory tests. Studies which assess system operating impacts and predicted performance will be used to select a family of the most promising liquid metals for a range of heat rejection temperatures between 400 and 100K. These studies will focus on all aspects of the LDR system including droplet generation and collection, insitu metal purification, and interactions with the power conversion system. Technology development efforts will be implemented for any deficiencies associated with the selected liquid metals. The program will conclude with appropriate testing to demonstrate the necessary technology is "in place" and confirm the analytical performance predictions.

TITLE:; Belt Radiator Dynamic Characteristics

PERFORMANCE PERIOD: Sep 90 - Sep 92

OBJECTIVE: Develop and experimentally validate an analytical dynamics code capable of evaluating various MBR concepts for a number of different operating conditions. An evaluation will be conducted of the currently available dynamic codes and modeling techniques for their suitability in modeling the MBR under zero "g" and microgravity conditions. Both steady state and transient operating conditions need to be modeled. The necessary experiments will be conducted to validate the code results and demonstrate the code's ability to model the MBR under expected operating conditions.

TITLE: Heat Pump Assessment Study

PERFORMANCE PERIOD: Jul 90 - May 91

OBJECTIVE: Analytically assess the current and advanced heat pump concepts for their potential operating improvements. Research and evaluation will be conducted of all known or proposed heat pump concepts followed by selection of the most promising for future study. Both thermally and electrically driven heat pumps will be included in this study. An assessment of the current state of development as well as estimation of the potential for future performance improvements for each of the selected concepts will be accomplished. Using these heat pump operating characteristics, the impact on overall system performance will be made for several representative thermal management applications.

TITLE: *Minimum Time Propellant Constrained Orbit Transfer*

PERFORMANCE PERIOD: Apr 90 - Mar 91

OBJECTIVE: Define the relationship between propulsion energy constraints and the potential to reduce orbit transfer times for a broad range of missions. The problem to solve will be formulated for the range of missions of interest. The problem formulation will next be implemented in order to parametrically define solutions. The third phase will provide fast running algorithms that may be implemented in specific application studies to quantify mission timeline benefits of propulsion investments. This is an [illegible] orbit transfer study problem and is purely analytical.

THERE ARE NO FY-90 AIR-LAUNCHED NEW STARTS

FY 90 BALLISTIC MISSILE PROPULSION PLANNED NEW STARTS

TITLE: Advanced Propellant/Bondline Evaluation

PERFORMANCE PERIOD: Aug 90 - Sep 93

OBJECTIVE: Bondline problems usually present themselves in new missile systems after selection and manufacturing commitment have been made, which indicates insufficient earlier characterization. Adequate bondline characterization has been limited by the lack of availability of meaningful tests. The most recent bondline tests need to be assessed in an advanced missile system and any needed test changes or developments used so that a thorough bondline characterization is possible. This will result in a new advanced missile system that is cheaper and that can be operational in a shorter time than normal. This is especially important for our strategic forces.

TITLE: Low Cost Artificial Intelligence Processing

PERFORMANCE PERIOD: May 90 - Aug 92

OBJECTIVE: Recent advances in computer logic control techniques and in the use of miniaturized instrumentation make the use of artificial intelligence (AI) techniques attractive for the long-cycle, complex processing of composite material components employed in solid propellant rocket motors. The objective of this program is to explore and utilize the AI processing technology initiated by AFWAL/ML, in the construction of representative nozzle composites and examine the cost savings potential of using such techniques for nozzle fabrication in making parts now costing in excess of $200,000 per unit.

FY 90 FUNDAMENTAL TECHNOLOGIES PLANNED NEW STARTS

TITLE: Microencapsulation

PERFORMANCE PERIOD: Jul 90 - Oct 92

OBJECTIVE: To determine the feasibility of encapsulating solid ingredients and to demonstrate the feasibility of using these ingredients in a state-of-the-art solid propellant. A two phase effort is planned to demonstrate microencapsulation of ingredients for solid propellents. Phase I is a feasibility evaluation to select materials for encapsulation to be formulated into a solid propellant. This phase will review encapsulation methods and assess material availability for encapsulation. Encapsulated ingredients will be formulated in pint mixes to evaluate propellant performance and properties. Phase II is the propellant demonstration of selected ingredients in small scale mixes and test motors.

TITLE: Low Slope/Extinguishable Propellants

PERFORMANCE PERIOD: Aug 90 - Nov 92

OBJECTIVE: There is a current need to develop methodology for restartable solid propellants for use in orbit transfer vehicles as well as in tactical and strategic missiles. Current solid rockets can be designed with a myriad of "pulses" but can not be shut off and re-ignited. This program will address the specific area of propellant extinguishment and re-ignition by tailoring the propellant chemistry. The payoff for space applications is decreased take-off weight relative to current liquid thrusters and trajectory "tailoring" for strategic and tactical missiles. Contract efforts would focus on the use of thermoplastic and other advanced binders in conjunction with alternate oxidizers to generate a zero burn rate (ZBR) at ambient pressure propellant. A study of negative catalysis would be conducted to yield a ZBR. The catalyst type and amount will be related to a baseline propellant to assess feasibility. Specifically, advanced binders and alternate oxidizers would be assessed with the inclusion of novel burn rate additives. The metallo-organic modifiers would be tested by strand-burn as well as small motor firings relative to baseline formulations. Task 1 will be to synthesize and screen modifiers in this fashion. Task 2 will include scaling up the most promising formulations for traditional as well as clean-burn formulations.

TITLE: Boundary Layer Code Validation

PERFORMANCE PERIOD: Oct 89 - Oct 92

OBJECTIVE: Large area ratio nozzles used in space engines cannot be accurately analyzed to determine performance and heat transfer characteristics because the boundary layer thickness and viscous flow losses are unknown. Codes under development to analyze such high area ratio nozzles must be validated and anchored with experimental data. This effort will validate the newly developed analytical tools and result in more accurate performance predictions for developing future space engines with improved reliability and reduced development costs. The effort will: review current boundary layer experimental work. Evaluate and select experimental techniques for collecting data in a simulated rocket engine environment. Develop measurement methods and diagnostics for measuring local skin friction, heat transfer, velocity, and pressure in the boundary layer. Collect data and use it to validate the previously developed analytical models.

TITLE: Nonconventional Performance

PERFORMANCE PERIOD: Oct 89 - Mar 92

OBJECTIVE: Numerous types of nonconventional nozzles are being examined for use on the next generation of launch vehicles. Current performance models are not capable of analyzing these nonconventional nozzles. The development of models to predict the performance of various nonconventional nozzle schemes will greatly assist the evaluation of designs of heavy lift launch vehicles and other space boosters. The developed models will allow the relative performance benefits of the various concepts to be assessed. The effort will: review existing nozzle performance prediction models for application to nonconventional nozzle configurations; identify nonconventional nozzle configurations such as dual throat/dual expander or plug-type nozzles which promise performance enhancement over conventional designs; select the most promising schemes for performance model development; develop computer models using computational fluid dynamics methods to predict the performance of the selected nonconventional configurations. Analyze the selected nonconventional nozzle configurations to evaluate potential performance benefits.

TITLE: Advanced Studies

PERFORMANCE PERIOD: Oct 89 - Oct 92

OBJECTIVE: To investigate the feasibility of a number of advanced concepts in propulsion and combustion technology to reduce the cost and increase the reliability and performance of weapons systems. Specifically there are six tasks which look promising at this time. The tasks and their objectives are: 1-Solid Propellant Catalysis Effects. Determine the mechanisms which cause plateau and super rate burning and apply this knowledge to the development of new propellants. 2-Steam Starter Cartridge Feasibility. Develop high performance pyrotechnic steam generator cartridge whose exhaust is clean and non-toxic for critical applications. 3-Acoustic Emission Failure Sensor. Develop automated system to detect hot gas leakage and burning rate abnormalities in solid rocket motors using nonintrusive acoustic sensors. 4-Magnetic Nozzle Studies. Continue the development of magnetic containment of hot gases to reduce nozzle heat transfer and produce thrust vector control. 5-Oblique Detonation Wave. Use the recently developed oblique detonation wave computational technology to determine the characteristics of oblique detonation wave tube launched vehicles. 6-Liquid Combustion Enhancement. Perform a conceptual study of ways to enhance liquid combustion efficiency and stability by the use of innovative techniques. An intensive in-house literature review shall be made, extensive discussions with industry and academic experts will be held, and preliminary calculations performed to select the most promising task(s). The contractor shall continue the literature review, determine feasibility, perform performance calculations and design, execute, and analyze laboratory experiments.

FY 90 FUNDAMENTAL TECHNOLOGIES PLANNED NEW STARTS (Continued)

TITLE: Application of Microconstitutive Theory

PERFORMANCE PERIOD: Apr 90 - Jul 93

OBJECTIVE: This program addresses the general problem of improving the accuracy of structural analysis and broadening the analysis applications to increasingly complex load histories for solid rocket motors. Current analysis codes are based upon generalizations of corrected linear viscoelasticity theories and are usually in error when expanded to untested geometries, temperatures, and load histories. There is a significant payoff in improved design and more accurate prediction of safety margins translating into improved motor reliability. This effort will build upon, apply, and verify a unique structural analysis code developed during an earlier contract. In order to apply the previously developed microstructural theory to actual solid propellant problems, the following tasks shall be conducted: Task 1 - Refinement of the existing theory shall assess the importance of propellant structural details (i.e., crystallinity, cooperative motion, plasticization, flaw treatments and verification) and incorporate coded descriptions of important effects; Task 2 - Build a material parametric data base for a wide range of binder chemistry and solids types; Task 3 - Imbed the refined propellant microstructural theory and its parameter data base into a full structural analysis code; Task 4 - Perform stress/strain filed calculations for arbitrary conditions of design requirement, environment, and load histories as well as predictions of absolute failure probability under critical conditions; Task 5 - Demonstrate theory's sensitivity to complexities in design, age processing, material inhomogeneities, and formulation variables; Tas 6 - Validate calculations with analog testing and subscale motor demonstrations.

TITLE: Motor Susceptibility to ESD

PERFORMANCE PERIOD: Dec 89 - Jun 93

OBJECTIVE: Develop an ESD susceptibility analysis methodology to significantly reduce the hazards of both traditional and unique procedures in solid rocket motor manufacturing, transportation, and deployment. Analysis and testing capabilities developed here will provide accurate assessments of ESD susceptibility for specific scenarios and result in supported recommendations for test standards. The program shall be comprised of the following tasks: Task 1 - Mechanisms of ESD; survey current mechanisms and refine deficiencies such as electric field calculations and breakdown path statistics. Task 2 - Improved ESD Testing; modify test apparatus to improve electrode configuration, isolate instruments from high voltage transients, and develop breakdown path detection capability. Task 3 - Propellant Microstructure; investigate propellant/liner/insulation/case additives to reduce susceptibility. Task 4 - Design Factors; evaluate sensitivity of ESD buildup and discharge to solid rocket motor design features. Task 5 - Effective System Grounding; identify critical grounding procedures for motors during processing, handling, and deployment, including mobile and space-based scenarios. Task 6 - Verification; prediction of ESD susceptibility for propellant sensitivity, design examples, and handling scenarios.

FY 90 FUNDAMENTAL TECHNOLOGIES PLANNED NEW STARTS (Continued)

TITLE: Propellant/Case Interface Aging

PERFORMANCE PERIOD: Jun 90 - Jun 93

OBJECTIVE: This program addresses the general problem of identifying and solving propellant/case bondline variabilities due to manufacturing "poisoning" problems. Currently, the industry has not been able to identify suspected adverse reactions between propellant bondline layers and nearly undetectable levels of migrating ingredients from motor case materials such as composite case resins, metal case adhesives and primers, and case insulation by-products and additives. This effort will provide significantly enhanced bondline analytical tools for propellant bondline manufacturing trouble-shooting as well as improved aging models for currently unknown interface reactions. The following is the program overview. Task 1 - identify zero-time and potential age-induced chemical interactions for HTPB-based and NEPE based propellants bonded to insulated composite case and adhesively bound steel case panels. Task 2 - develop quantitative methods to assess the impact of Task 1 interactions upon bondline integrity of representative case/insulation/propellant regions of ballistic, tactical, and space motors. Task 3 - using Task II measurement techniques, sensitive bondline mechanical property tests, and standard chemical analysis, develop a zero-time data base. Task 4 - from analysis of data base, select new materials or processing approaches to minimize suspected aging interactions. Task 5 - identify preliminary aging models and verify to the extent possible.

TITLE: HEDM Candidate Concentration

PERFORMANCE PERIOD: Jan 90 - May 93

OBJECTIVE: To take promising compounds from the High Energy Density Matter contracts and store them in high enough concentrations to determine their bulk properties. None of the HEDM candidates identified in the initial phase of the HEDM plan have been made in microscopic quantities. The projects initiated under this PRDA will attempt to do this and to determine their properties. This effort answers the need to create experimental quantities of potential new high energy propellants, eventually leading to higher rocket payloads per dollar in most missions. The major tasks of this effort are to verify predicted HEDM properties and determine how to synthesize bulk quantities. Innovative proposals will be sought under a PRDA and eight to ten will be selected for funding. Typically these will involve efforts to maximize concentration of previously identified HEDM candidates.

FY 90 FUNDAMENTAL TECHNOLOGIES PLANNED NEW STARTS (Continued)

TITLE: HEDM Applications Study

PERFORMANCE PERIOD: May 90 - Nov 92

OBJECTIVE: This program would exploit postive results that have come out of the HEDM research efforts. HEDM materials have been identified, both theoretically and experimentally, that appear to be good energy storage candidates and warrant further exploration. The objective of this program is to determine appropriate HEDM applications. Near-term applications will be emphasized. Several HEDM materials have been identified as a result of ongoing HEDM research. These materials have tended to fall into a few general classes of materials; such as cryogenic solids, high energy additives, dormant propellants (energized just before use) and externally stabilized materials. This program will assess and develop potential applications for these classes of materials. The major tasks of this effort will be to define the state-of-the-art in HEDM manufacture, create a set of possible astronautics-related uses, and evaluate the feasibility of these applications. The methodology used to perform the tasks will include data gathering, critical evalaution and verification.